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EXPERIMENTAL FREEZING SHOCK

CHANGES IN BODY FLUIDS AND TISSUES

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The thermal injury due to freezing causes the loss of large amounts of protein-containing fluid at the site of thawing tissues; this was demonstrated by Harkins and associates.[1] This fluid is derived from the circulating blood plasma, and its loss is accompanied by the development of shock. Mahoney [2] has demonstrated that a similar type of shock results from cooling of peritoneal surfaces. In these respects thermal injuries due to freezing and burns resemble each other closely. In a recent book the clinical applications of these observations have been reemphasized by Harkins.[3] Sir Thomas Lewis [4] described the damage to capillaries, the development of edema and other changes following frostbite.

This study was aided by a grant from Abbott Laboratories, North Chicago, Ill.

From the William Buchanan Blood, Plasma and Serum Center, Baylor University Hospital, and the Department of Pathology, Baylor University College of Medicine.

1. Harkins, H. N.: Shock Due to Freezing: I. Shift of Body Fluids and Associated Blood Concentration Changes, Proc. Soc. Exper. Biol. & Med. **32**:432-434 (Dec.) 1934. Harkins, H. N., and Hudson, J. E.: Shock Due to Freezing: II. Composition of Edema Fluid, ibid. **32**:434-435 (Dec.) 1934. Harkins, H. N., and Harmon, P. H.: Experimental Freezing: Bleeding Volume, General and Local Temperature Changes, ibid. **32**:1142-1143 (April) 1935.

2. Mahoney, E. B.: A Study of Experimental and Clinical Shock with Special Reference to Its Treatment by the Intravenous Injection of Preserved Plasma, Ann. Surg. **108**:178-193 (Aug.) 1938.

3. Harkins, H. N.: The Treatment of Burns, Springfield, Ill., Charles C. Thomas, Publisher, 1942.

4. Lewis, T.: Observations on Some Normal and Injurious Effects of Cold upon the Skin and Underlying Tissues: III. Frost-Bite, Brit. M. J. **2**:869-871 (Dec. 20) 1941.

In attempting to produce a pronounced diminution in the blood volume of experimental animals due solely to the loss of plasma from the vascular system, we have found that a modification of Harkins' freezing technic is reliable, consistent in results and simple to perform. Uniform events leading to fatal shock may be expected in each animal after one hindlimb has been severely frozen. This course usually extends over a period of six to ten hours. The effects of the depletion of plasma volume on the tissues both early and late in the experimental period can be observed by arresting the experiment at different intervals. Additional interest in this form of injury results from the probable occurrence of a similar type of shock clinically on modern battlefields, such as the present Russian front.

The method of production of the freezing injury, the apparent shifts of body fluid and the early and late pathologic changes in the various organs, observed grossly and microscopically, are reported at the present time. The effects of therapy with various solutions of serum protein on these and on other animals will be presented later.[5]

METHODS

Harkins' technic of producing freezing shock, which consists of the application of solid carbon dioxide to one half of the body surface, has been modified in the following manner: The freezing injury was produced by submerging one hindlimb of a medium-sized dog in a freezing solution composed of solid carbon dioxide and 95 per cent alcohol. Approximately 8 pounds (3.6 Kg.) of crushed solid carbon dioxide was placed in a galvanized bucket with a capacity of 2 gallons (7.5 liters). To this 4 to 6 quarts (3.8 to 5.7 liters) of 95 per cent alcohol was added with constant stirring. In ten to fifteen minutes the alcohol became syrupy and reached a temperature well below —40 F.[6] A half-moon niche along the upper edge of the bucket facilitated the placing of the hindlimb in the freezing mixture. With proper care foaming of the mixture was kept at a minimum. Most of the alcohol was reclaimed later for use in further experiments by filtering it after it had reassumed room temperature.

Medium-sized dogs were subjected to anesthesia induced by slow intravenous injection of 1 grain (0.06 Gm.) of soluble pentobarbital U. S. P. (pentobarbital sodium) for every 5 pounds (2.3 Kg.) of body weight. While the lumps of solid carbon dioxide were agitated with a stirring rod, one hindlimb of the animal was placed in the solution for twenty-five minutes. By placing an asbestos pad against the abdomen an attempt was made to prevent freezing of the abdominal wall. With this protection the freezing extended only slightly above the inguinal ligament. After twenty-five minutes the limb was frozen solid and the freeze extended to the bones (femur and tibia). The dog was then placed on the board,

5. Muirhead, E. E.; Ashworth, C. T.; Kregel, L. A., and Hill, J. M.: The Therapy of Shock in Experimental Animals with Plasma Protein Solutions: II. Fluid Distribution in the Body and Its Relation to Treatment with Concentrated and Dilute Serum Solutions and Saline Solutions, unpublished data.

6. The resistance thermometer used for measuring the temperature of the mixture read temperatures to —40 F. only.

and the frozen limb was allowed to thaw at room temperature. The thawing was fairly complete in one to one and one-half hours. As the thawing proceeded the plasma volume decreased. The blood pressure was usually sustained slightly below the control level until fairly late, i. e. five to six hours. Then it dropped either gradually or fairly rapidly, and the animal died approximately eight to twelve hours after the freeze. After its death the extremities were weighed according to the Blalock technic.[7]

In the present experiments the mean arterial pressure was taken by means of a carotid cannula and a mercury manometer. Samples of blood were taken from the femoral and jugular veins, and heparin was used as anticoagulant. The following values were determined before and during shock: hemoglobin concentration of the blood,[8] hematocrit reading,[9] red blood cell count,[10] plasma protein concentration,[11] plasma volume,[12] total circulating proteins, water available for the solution of sodium thiocyanate,[13] plasma sodium concentration[14] and carbon dioxide-combining power of the plasma.[15] The samples of plasma taken during shock invariably were stained with hemoglobin, which indicated that hemolysis had occurred. The possible causes for the hemolysis are discussed hereinafter.

Postmortem examinations of the animals were performed. Tissue was obtained for microscopic examination from the lungs, myocardium, liver, ileum, stomach, spleen, kidneys and adrenal glands and from the muscles and subcutaneous tissues of the frozen limb for microscopic examination. The tissues were stained by the usual hematoxylin-eosin technic.

RESULTS

The blood pressure was usually depressed for a few minutes immediately following the freeze but soon returned to a level slightly below the control level. Rarely, it was transiently elevated above the control level for a short interval. It remained near the control level for five to

7. Blalock, A.: Experimental Shock: A Cause of Low Blood Pressure Produced by Muscle Injury, Arch. Surg. **20**:959-996 (June) 1930.

8. Sanford, A. H., and Sheard, C.: The Determination of Hemoglobin with the Photoelectrometer, J. Lab. & Clin. Med. **15**:483-489 (Jan.) 1930.

9. Wintrobe, M. M.: A Simple and Accurate Hematocrit, J. Lab. & Clin. Med. **15**:287-289 (Dec.) 1929.

10. The red cells in twenty hemocytometer squares were counted on each occasion. The red cell counts are not reported in the table but will be presented later.[5]

11. Greenberg, D. M.: The Colorimetric Determination of the Serum Proteins, J. Biol. Chem. **82**:545-550 (May) 1929.

12. Gregerson, M. D.; Gibson, J. J., and Stead, E. A.: Volume Determination with Dyes, Am. J. Physiol. **113**:54 (Sept.) 1935.

13. Crandall, L. A., and Anderson, M. X.: Estimation of the State of Hydration of the Body or the Amount of Water Available for the Solution of Sodium Thiocyanate, Am. J. Digest. Dis. & Nutrition **1**:126-131 (April) 1934.

14. Butler, A. M., and Tuthill, E.: An application of the Uranyl Zinc Acetate Method for Determination of Sodium in Biological Material, J. Biol. Chem. **93**: 171-180 (Sept.) 1931.

15. Exton, W. G.; Schattner, F., and Rose, A. R.: Acidosis and Alkalosis: Clinical Significance and Measurement by Colorimetry of Plasma CO_2 Capacity, Am. J. Clin. Path. **11**:632-642 (Aug.) 1941.

eight hours, after which it usually dropped gradually to a severe shock level. This late drop was always indicative of impending death. Occasionally, the final drop was sudden with a rapid termination. Hemoconcentration could be observed as soon as thawing began, frequently within a few minutes, and was progressive for an average of five to six hours, after which it remained at a fairly stabilized peak until death. With the hemoconcentration there was a corresponding severe depletion of plasma volume and of total circulating proteins. The concentration of plasma protein was slightly modified by the free hemoglobin present (usually 0.1 to 0.3 Gm. per hundred cubic centimeters) but was not

TABLE 1.—*Blood Pressure and Body Fluid Changes in Six Dogs Before and During Shock* *

Dog	Weight, Kg.	Period	Interval for Development of Late Shock, Hr.	Blood Pressure, Mm. of Mercury	Hemoglobin, Gm. per 100 Cc.	Hematocrit Reading, per Cent	Plasma Volume, Cc.	Plasma Protein, Gm. per 100 Cc.	Total Circulating Proteins, Gm.	Extracellular Water, Cc.	Interstitial Water, Cc.	Plasma Sodium, Mg. per 100 Cc.	Plasma Carbon Dioxide-Combining Power, Vols. per Cent
7S	9.3	Control		165	15.50	47.0	485	6.10	29.6	3,470	2,985	340	52.6
		Shock	4.5	65	20.10	67.0	265	5.50	14.5	3,280	3,015	346	45.5
12S	8.5	Control		150	15.10	51.5	400	6.20	24.8	2,450	2,050	352	55.5
		Shock	9.5	60	21.00	78.0	265	6.50	17.2	1,520	1,255	374	37.0
13S	10.0	Control		160	12.35	38.5	470	6.10	28.6	1,930	1,460	314	52.0
		Shock	6.5	50	21.15	71.0	210	6.15	12.8	1,340	1,130	355	37.0
15S	7.5	Control		160	15.00	47.0	354	....	....	1,850	1,496	323	68.0
		Shock	7.5	50	21.15	74.0	145	....	....	1,540	1,395	364	41.5
18S	9.1	Control		160	12.80	40.4	525	6.45	33.8	4,040	3,515	376	53.4
		Shock	6.0	55	20.15	60.0	208	5.90	16.7	2,650	2,442	506	25.3
19S	8.5	Control		130	13.25	38.5	470	6.55	30.5	.....	.....	365	45.5
		Shock	7.5	54	19.15	60.0	278	6.70	18.6	.....	.....	415	21.3
Average	8.8	Control		154	14.00	43.6	450	6.27	29.4	2,748	2,301	345	54.5
		Shock	6.9	56	20.45	66.6	229	6.15	15.9	2,066	1,847	393	34.6

* The weights of the extremities were modified by the treatment and are not recorded here.

consistently changed in any one direction. The water available for the solution of sodium thiocyanate (considered as extracellular water) was consistently decreased. The plasma sodium concentration was increased. These two separate findings are taken to indicate a decrease in extracellular fluid volume. The apparent decrease in extracellular fluid plus an increase in the sodium ion concentration suggests that fluid enters body cells in the late phases of this type of shock. The carbon dioxide–combining power was greatly depressed. The edema fluid of the frozen leg contained an average of 4.0 Gm. of proteins per hundred cubic centimeters. When allowed to stand in a test tube, this fluid clotted.

Fifty dogs have been subjected to this type of shock, 29 of which constitute the basis of this study. The changes in blood pressure and in the body fluids in 6 dogs during shock are presented in table 1. The

effects of therapy with dilute and concentrated solutions of serum and solutions of sodium chloride during the late phase of this shock in 19 dogs will be discussed in a separate report.[5]

PATHOLOGIC CHANGES

The tissues of the various organs of different animals were observed at various intervals during the course of the experiments. The pathologic changes in the various organs will be described under two separate heads: First, the changes in the interval up to two and one-half hours after the freeze was completed are described as early observations. Second, the changes noted of the organs when death occurred four or more hours after the freeze are considered under late observations.

Early Observations.—Gross Examination: The lungs were pink, were air containing throughout and had dry cut surfaces. The blood that dripped from the cut vessels was usually thick and dark. The pleural spaces and the pericardial sac had no excess of fluid. The myocardium was usually flabby, and the chambers contained a small amount of blood.

The intestines were contracted and pale. The intestinal mucosa was pale. There was no excess fluid in the peritoneal cavity. The cut surface of the liver was brown and oozed thick and dark blood from the larger vessels. The spleen was partly or completely contracted and usually weighed about 20 Gm. Gross changes in the adrenal glands were not discernible.

The appearance of the frozen leg depended on whether thawing had been complete or not. Immediately after the freeze and for a time up to fifteen to forty-five minutes after, the frozen tissues could be seen to extend down to the bones of the limb. The tissues were firm and fairly pale. As thawing proceeded, the skin, the subcutaneous tissue and the muscles became extremely edematous. When a blue dye had been given intravenously, the edema fluid subsequently stained blue. The small vessels and the capillaries were everywhere prominent and dilated. The femoral artery occasionally contained a thrombus, but the vein was usually not obstructed. The skin and the subcutaneous tissue of the other limbs were pale and did not appear edematous.

Microscopic Examination: In general, the microscopic changes in shock are vascular, interstitial and cellular. The vascular manifestations are dilatation of venules and capillaries. The interstitial changes consist of edema, infiltration by polymorphonuclear neutrophilic leukocytes and capillary hemorrhages. The cellular changes as considered are confined to parenchymatous organs, such as the liver, the kidneys and the adrenal glands. They are characterized by pyknosis and karyolysis; droplet degeneration of the cytoplasm; acute parenchymatous degeneration, and focal necrosis, atrophy and necrobiosis. These changes have been classified as slight, moderate and marked.

The studies in the period up to two and a half hours revealed slight or no vascular changes and usually no cellular changes in the viscera. The absence or meagerness of the changes was particularly evident in the period up to the first hour. The vascular manifestations in the lungs when present were venular dilatation and extremely slight capillary hyperemia. In the liver venosinusoidal hyperemia was slight or moderate and focal. The kidneys were more prone to display patchy hyperemia. This focal dilatation of capillaries was observed particularly in glomeruli which had only a portion of their capillary loops open and in the peritubular capillaries. The gastric and the intestinal mucosa were normal in appearance. Edema in the frozen leg was proportionate to the state of thawing.

The adrenal glands require special mention. Hyperemia was slight or absent in the cortex and the medulla. The zona fasciculata of the cortex invariably revealed infiltration with polymorphonuclear neutrophilic leukocytes. On one occasion this infiltration was prominent thirteen minutes after the freeze. The parenchymatous cells in this layer appeared well preserved but exhibited a slight decrease in lipid content.

In the 29 carefully studied dogs the interval between the inception of the anesthesia induced with soluble pentobarbital and the beginning of the freeze averaged one hour and twenty-nine minutes. The same period for the 6 dogs studied in the early period following the freeze averaged one hour and twenty minutes. The highest time of this interval for any one dog was two hours and twenty minutes. The adrenal glands from 5 normal dogs killed by a fatal hemorrhage during ether anesthesia were examined microscopically; these animals were considered the basic "anesthesia controls." Four other dogs were subjected to and killed under anesthesia induced with intravenous soluble pentobarbital, and their adrenal glands were studied microscopically; these animals also were used as anesthesia controls. Two of the latter dogs were killed by rapid intravenous injection of additional soluble pentobarbital (5 to 8 grains [0.32 to 0.52 Gm.]) one and one-half hours after the inception of the narcosis. The other 2 dogs were similarly killed two and one-half hours after the inception of the narcosis. The adrenal glands from the ether controls and the soluble pentobarbital controls were identical in appearance, and neither revealed any deviation from the normal appearance. Particularly noticeable was the absence of infiltration by polymorphonuclear neutrophilic leukocytes. Dunphy, Gibson and Keeley [16] observed mild leukocytic infiltration of the adrenal cortex following anesthesia induced with soluble pentobarbital. The

16. Dunphy, J. E.; Gibson, J. G., II, and Keeley, J. L.: Observations on the Pathology of Experimental Traumatic Shock, Surg., Gynec. & Obst. **72**:832-833 (May) 1941.

absence of such infiltration in our controls may have been due to the fact that our control animals were killed sooner in order to correspond to the animals studied in the early period following the freeze (up to two and one-half hours).

Other microscopic changes in the anesthesia control dogs require consideration. After two and one-half hours of narcosis there were moderate capillariovenous hyperemia of the lungs, slight venosinusoidal hyperemia of the liver and focal capillariovenous hyperemia of glomerular and peritubular vessels of the kidneys. No interstitial or cellular changes were observed. These manifestations are similar to the occasional mild ones already mentioned as present in the early period following the freeze.

Late Observations.—Gross Examination: No serous effusions were observed. The lungs and the liver when sectioned oozed thick and dark blood. Pulmonary edema was evident grossly in a few instances. The heart ceased beating in diastole. The spleen was always firmly contracted. The intestines were as frequently relaxed as contracted. The intestinal mucosa was dark red. The adrenal cortex next to the medulla was often red.

The thawed limb was very much swollen. The edema was greatest in the subcutaneous tissues. The capillaries were extremely prominent. The soft tissues of the other limbs were pale and displayed no gross edema.

Microscopic Examination: In each case there was a distinct contrast between the picture in this late period and the early observations already mentioned. The vascular changes were everywhere marked. The venules and the capillaries of the lungs were prominent, frequently giving the alveolar wall a beaded appearance. There were capillary hemorrhages into the alveolar spaces. The evidences of alveolar edema were frequently striking, and occasionally perivascular and peribronchial edema were present. Polymorphonuclear neutrophilic leukocytes were prominent within capillaries and at times assumed an interstitial position. The capillaries and the venules of the myocardium were open diffusely. Over most fields each muscle fiber was bounded by a dilated capillary. In longitudinal section these capillaries formed streaks which frequently intercommunicated. In cross section the appearance was of a red cell partly surrounded by an endothelial cell nucleus of semilunar shape. The venosinusoidal dilatation in the liver was marked. The contraction of the spleen was evident microscopically by the small amount of blood present and the condensation of splenic corpuscles, trabeculae and pulp cells. Frequently polymorphonuclear leukocytes were more numerous than normal. The dilatation of the capillaries in the kidneys was very prominent. Most of the glomeruli became noticeable because of capillary loops that were stuffed with red cells. The

dilatation in each glomerulus was diffuse. The peritubular capillaries of both the cortex and the medulla were likewise prominent. In the medulla each tubule was flanked by a widely dilated capillary. The capillaries of the intestinal and the gastric mucosa were prominent. The appearance of these vessels in the muscles of the frozen limb resembled the description by Krogh [17] of muscles during marked activity.

The interstitial changes depended greatly on the organ studied. In the lung there occurred marked edema, capillary hemorrhages and interstitial infiltration with leukocytes. The liver, the kidneys and the intestinal mucosa revealed no definite interstitial changes, apparently because these regions do not have much room for the accumulation of edema fluid. The interstitial changes were greatest in the frozen limb. There was marked edema in the skin and the muscles and particularly in the subcutaneous tissue. There was precipitation of a fibrin network in this edema. Furthermore, a definite polymorphonuclear leukocytic infiltration was present; this means that the extravasation of fluid had the characteristics of an exudate.

The cellular changes were most pronounced in the liver, the kidneys, the adrenal glands and the muscle fibers of the frozen limb. Microscopic alterations of the myocardial fibers could not be identified.

Under normal conditions the hepatic cells may be lighter in staining toward the center of the lobule and much darker about the portal canals. This difference in staining is possibly associated with the distribution of glycogen in the lobule. In the late phases of freezing shock the cells stained equally throughout the lobule. There was a tendency for such cells to be darker, more granular and somewhat swollen and to have distinct cytoplasmic boundaries. These changes are considered as acute parenchymatous degeneration and depletion of glycogen. The predominance of droplets in the cytoplasm and the presence of focal areas of necrosis involving groups of three to five cells were additional cellular changes noticed in these studies. In the convoluted tubules of the kidney similar observations were made. However, the most outstanding and definite changes were seen in the zona fasciculata of the adrenal cortex. The lipid content of the cells was definitely decreased. The first indication that important changes had occurred in this layer was that it became difficult to follow the cords of cells from the zona glomerulosa all the way to the zona reticularis owing to necrobiosis of the cells and disruption of the cell cords. There were focal karyolysis and necrosis. Polymorphonuclear leukocytes were abundant. These cells accumulated about areas of necrosis and showed degenerative changes comparable to those seen about suppurative foci.

17. Krogh, A.: The Anatomy and Physiology of Capillaries, New Haven, Conn., Yale University Press, 1922.

In the present series these changes were greatest in the inner half of the zona fasciculata.

The muscle fibers of the frozen limb displayed loss of striation with hyalinization, fractures, marked granularity and outright necrosis.

RELATION OF LOSS OF PLASMA TO DAMAGE OF CAPILLARIES AND TISSUES

The pathologic changes observed may be analyzed in relation to the time and the extent of depletion of plasma or blood volume.

Figure 1 represents the relation of hemoconcentration to the time intervals in 22 dogs subjected to freezing shock. The spread in the

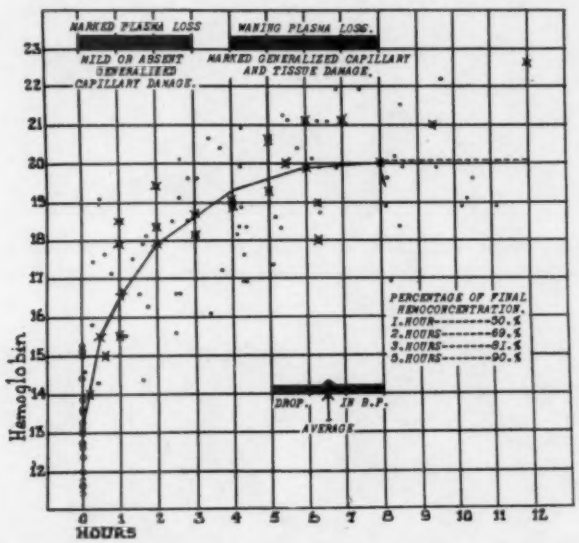

Fig. 1.—Chart showing hemoconcentration in freezing shock. The curve is an average curve taken from 106 hemoglobin values (photoelectric method expressed in grams per hundred cubic centimeters) for 22 animals shocked by the freezing procedure. The percentage of final hemoconcentration is taken to indicate the extent of loss of plasma. On such a basis it is noted that the greatest amount of loss occurs early (first three hours), when generalized capillary dilatation and parenchymatous damage are meager or absent. Hemoconcentration tends to level off or cease when the peripheral arterial pressure drops.

points from which the average curve was obtained is due to the spread of the control values. Only two curves originated below the average control hemoglobin curve and extended above the average curve. It may be argued that the early part of this curve is influenced by splenic contraction, with the release of red cells. It is conceivable that in a normal 10 Kg. dog the spleen may contain 60 to 80 cc. of blood with a

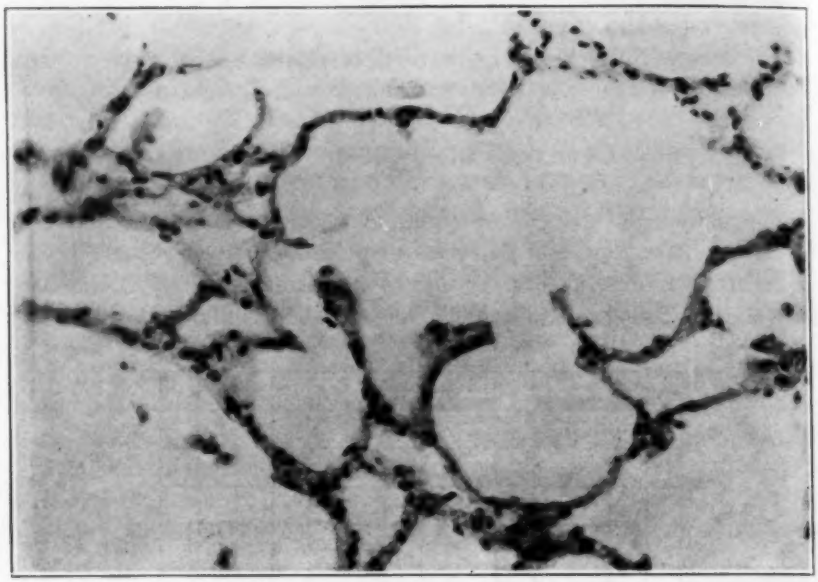

Fig. 2.—Photomicrograph of a section of a lung taken during the control period after two and a half hours of anesthesia induced with soluble pentobarbital.

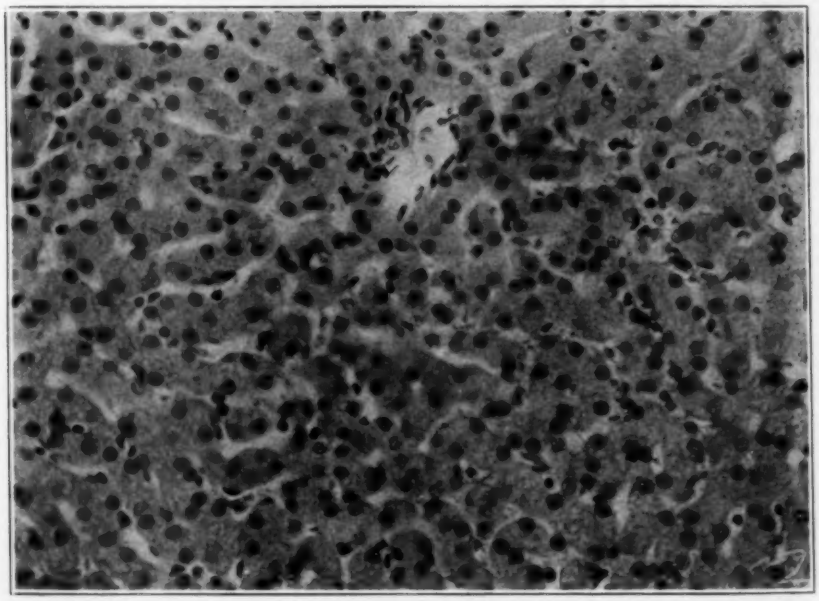

Fig. 3.—Photomicrograph of a section of the liver (central vein present) taken during the control period after two and a half hours of anesthesia induced with soluble pentobarbital.

higher hematocrit value than is present in the general circulation. Theoretically, if the entire 60 cc. were composed of red blood cells and were released to the general circulation, each point on the average curve would be higher than expected from loss of plasma alone by 1 Gm. per hundred cubic centimeters. The conformity of the curve would not change appreciably, but the per cent of the final hemoconcentration would be slightly lower for each hour if the 1 Gm. correction were made. The subsequent deductions from this curve would still hold true. Studies of plasma volume (table 2), however, indicate that added red blood cells have not influenced the curve as presented in figure 1.

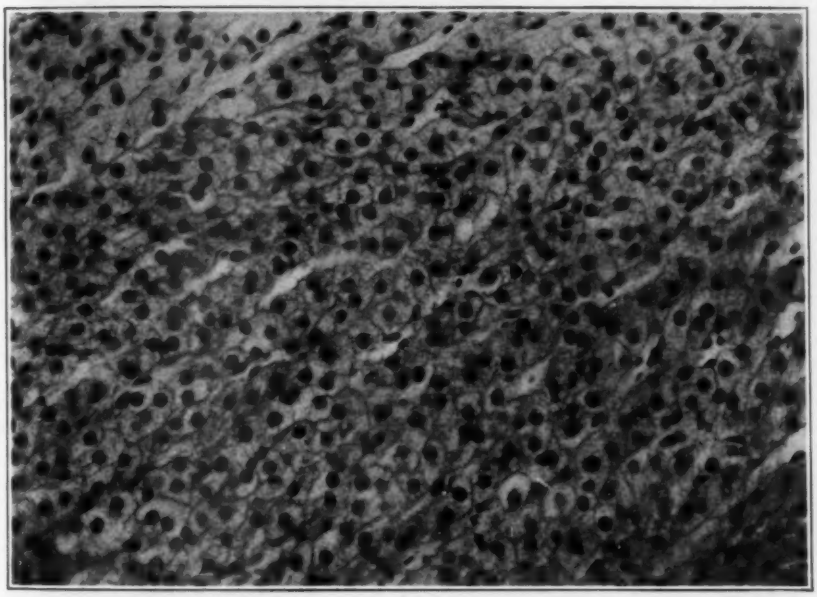

Fig. 4.—Photomicrograph of a section of the adrenal cortex (zona fasciculata) taken during the control period after two and a half hours of anesthesia induced with soluble pentobarbital.

Since in this type of shock the depletion of blood volume is strictly due to loss of plasma, the degree of hemoconcentration reflects the amount of depletion of blood volume. If one considers the final concentration of hemoglobin as 100 per cent hemoconcentration, then by considering the hourly concentration as reflected on the curve one can define the hourly percentage of final hemoconcentration. This percentage of final hemoconcentration reflects the average loss of plasma at that time. On such a basis it is striking that the loss of plasma is greatest during the first two and one-half to three hours. This is the interval during which the evidences of generalized damage to the capillaries and tissues as obtained by microscopic study are meager.

TABLE 2.—*Microscopic Observations on (a) Typical Control Dogs Killed During Anesthesia Induced with Soluble Pentobarbital; (b) Dogs Two and a Half Hours After Freeze, and (c) Dogs Four Hours or More After Freeze* *

Dog	Weight, Kg.	Comment	Period	Plasma Volume, Cc.	Hemoglobin, Gm. per 100 Cc.	Hematocrit, per Cent	Lungs	Myocardium	Liver	Spleen	Kidneys	Adrenal Glands	Intestines	Frozen Leg
N.IV	11.6	Two and a half hours under anesthesia induced with soluble pentobarbital; autopsy done immediately after death	.....	...	....	....	Slight to absent capillariovenous hyperemia	Normal appearance	Slight venosinusoidal hyperemia	Moderate amount of blood in sinusoids	Normal appearance	Normal appearance	Normal appearance	Skeletal muscle normal in appearance
28S	10	Killed 2½ hours after freeze (early period); immediate autopsy	Control	600	12.9	...	Slight to absent capillariovenous hyperemia	Normal appearance	Moderate venosinusoidal hyperemia	Slight amount of blood in sinusoids	Cortex normal; slight peritubular hyperemia in medulla	Slight infiltration of cortex by leukocytes	Normal appearance	Edema and marked capillariovenous hyperemia
			Just before killing	375	19.5									
3S	12	Killed 4½ hours after freeze (late period); immediate autopsy	Control	...	15.3	46.5	Marked capillariovenous hyperemia; focal hemorrhages	Marked capillariovenous hyperemia	Biopsy before freeze: normal appearance. Shock period: marked venosinusoidal hyperemia; atrophy of cord cells; distended lymphatics	Little blood; markedly contracted	Marked capillariovenous hyperemia in glomerular and peritubular regions; no degeneration of tubular epithelium	Marked capillary hyperemia and focal hemorrhages of cortex; marked leukocytic infiltration of cortex; necrobiosis and loss of lipoid of cortical cells	.....	Marked capillariovenous hyperemia and edema between fibers; loss of striations; granularity and fractures of muscle fibers
			Just before killing	...	22.7	80								
17S	9.8	Death 8 hours after freeze (late period); immediate autopsy	Control	517	13.6	43.1	Marked venous hyperemia; moderate capillary hyperemia; slight interstitial leukocytic infiltration	Marked capillariovenous hyperemia	Moderate to marked venosinusoidal hyperemia; acute parenchymatous degeneration of cord cells	Marked contraction; small amount of blood	Marked cortical and medullary capillariovenous hyperemia; albuminuria; acute parenchymatous degeneration	Marked leukocyte infiltration of cortex; degenerative changes of cortical cells (zona fasciculata and reticularis)	Marked capillary hyperemia of villi	Marked capillariovenous hypermeia and edema
			2 hours before death	300	18.65	63.1								
			1 hour before death	...	19.15	67.6								

* The series included the examination of tissues from 4 normal dogs killed by fatal hemorrhage during ether anesthesia, 4 dogs killed after the induction of anesthesia with soluble pentobarbital, 6 dogs killed in the early period after the freeze (up to two and a half hours) and 8 dogs which were killed or died in the late period (beyond four hours after the freeze).

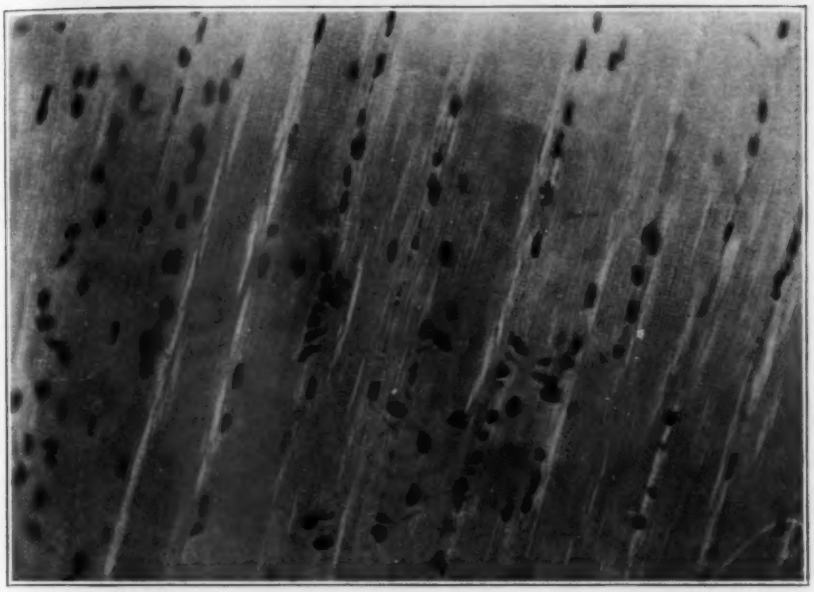

Fig. 5.—Photomicrograph of a section of skeletal muscle (lower extremity) taken during the control period after two and a half hours of anesthesia induced with soluble pentobarbital.

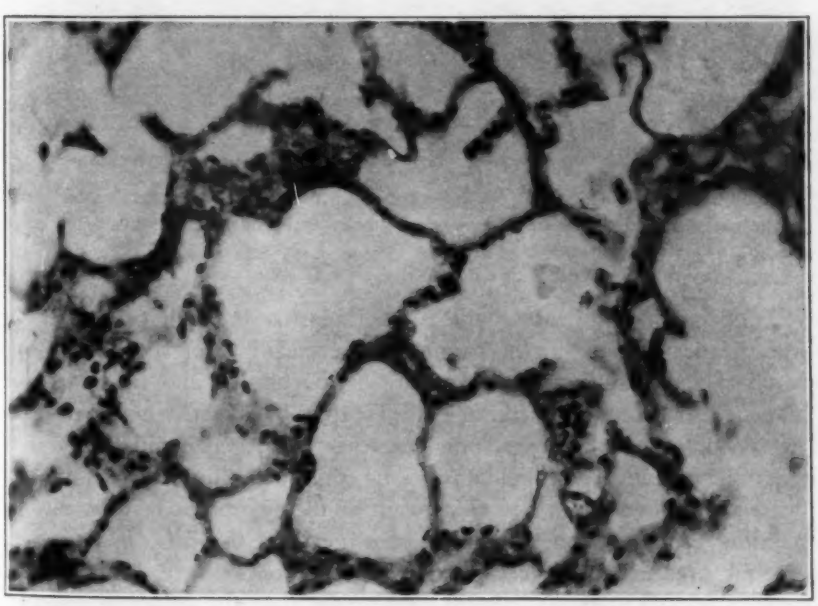

Fig. 6.—Photomicrograph of a section of a lung taken during the early period of the development of freezing shock (two and a half hours after severe freeze).

* The series included the examination of tissues from 4 normal dogs killed by fatal hemorrhage during ether anesthesia, 4 dogs killed after the induction of anesthesia with soluble pentobarbital, 6 dogs killed in the early period after the freeze (up to two and a half hours) and 8 dogs which were killed or died in the late period (beyond four hours after the freeze).

Conversely, when loss of plasma begins to wane, the generalized damage is greatest.

It is also of interest to note that in this form of shock hemoconcentration tends to reach a fairly stabilized peak at approximately six hours. This cessation of loss of plasma corresponds to the interval when the blood pressure drops markedly. The decrease in loss of plasma is partly related to a great decrease in the volume of plasma that is available. Yet on the basis of the advanced generalized damage to the capillaries hemoconcentration should continue until death.

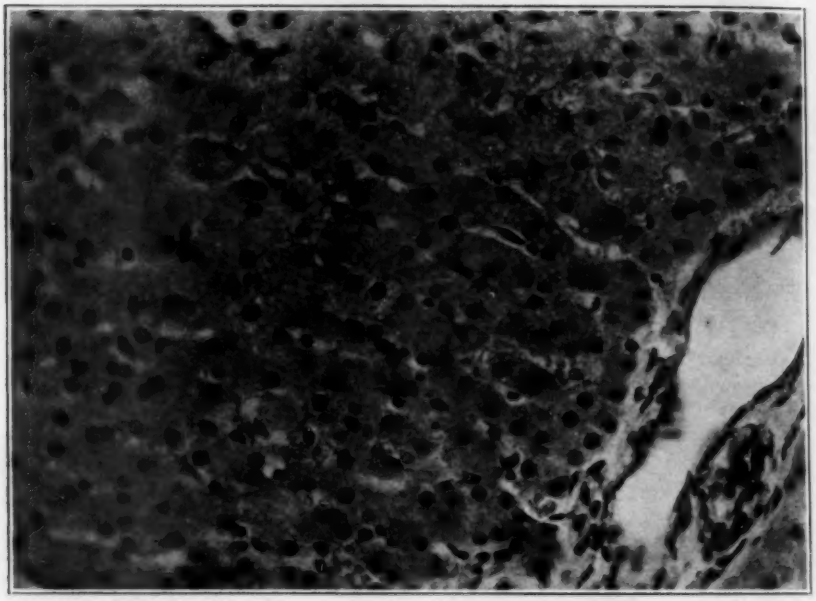

Fig. 7.—Photomicrograph of a section of the liver (near central vein) taken in the early period of the development of shock (two and a half hours after severe freeze).

The factors influencing the loss of plasma through capillaries are hydrostatic pressure in the capillaries, permeability of the walls of the capillaries, colloidal osmotic pressure of the plasma and tissue tension. The first two factors encourage the escape of plasma, whereas the last two tend to retard it. In spite of greatly damaged capillaries and no apparent change in colloidal osmotic pressure, loss of plasma may decrease markedly or cease as a result of the two other factors, viz. the building up of tension at the site of injury and the drop in peripheral arterial pressure and in capillary hydrostatic pressure. Thus, these various factors may so balance each other that the effective outgoing force is insufficient to push plasma out in spite of greatly damaged capillaries.

CONSIDERATION OF LABORATORY TESTS USED

At the present time the various tests used in the study of distribution of fluid in this and in other forms of shock may be partly subject to criticism. Nevertheless, certain deductions can be made from the tests used, and definite trends can be developed, even if strictly quantitative interpretation may be subject to question at the present time. A partial appraisal of these tests may be obtained from the examination of possible criticisms.

It is known that the blue dye (Evans' blue) technic for determination of plasma volume may be faulty when marked endothelial damage exists.

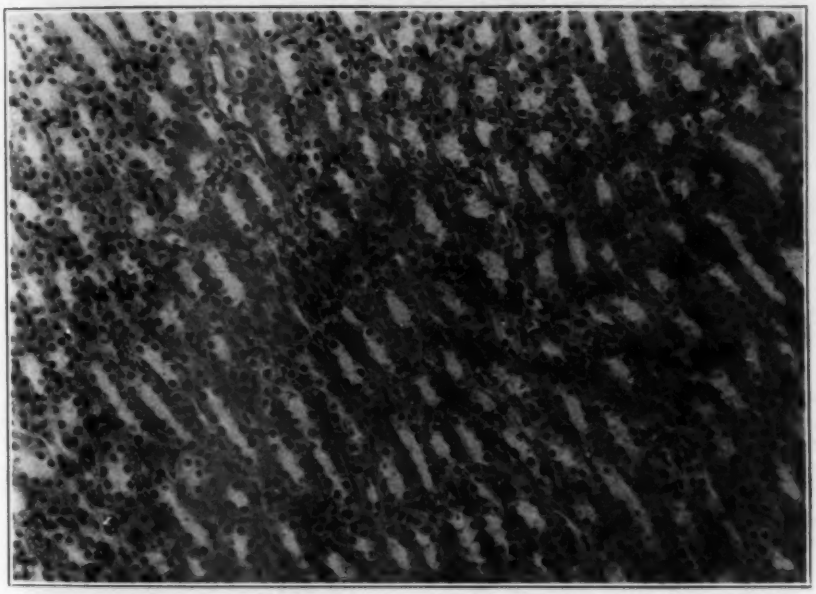

Fig. 8.—Photomicrograph of a section of kidney (medulla) taken in the early period of development of shock (two and a half hours after severe freeze).

The error may result from the loss of dye into the damaged area and from possible lack of complete mixing. These arguments are weakened by other findings. The mixing time has been found to be adequate in hemorrhagic shock.[18] While the loss of dye tends to make determined values for plasma volume higher than expected, in actual practice the concentration of the dye in the plasma remains so close to a stabilized point for five to fifteen minutes after thorough mixing that even with

18. Ebert, R. V.; Stead, E. A., Jr.; Warren, J. V., and Watts, W. E.: Plasma Protein Replacement After Hemorrhage in Dogs With and Without Shock, Am. J. Physiol. **136**:299-305 (April) 1942.

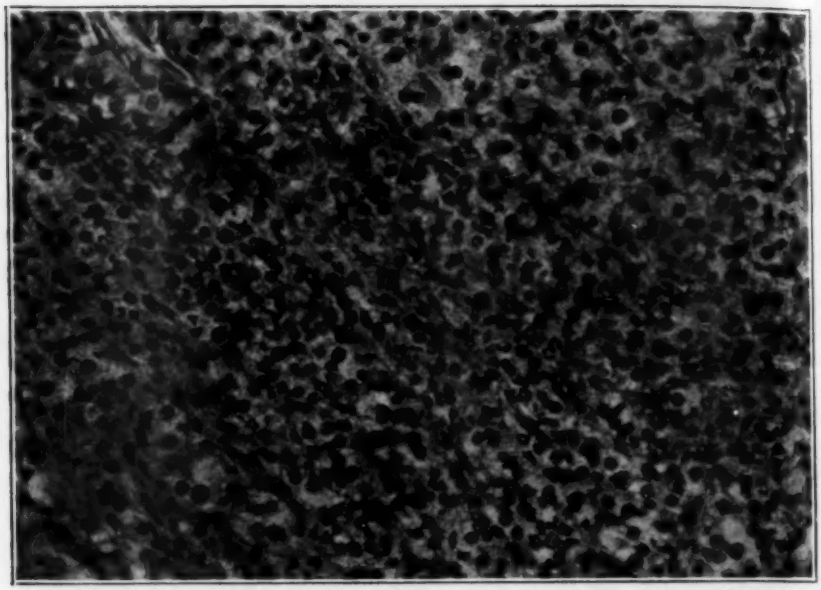

Fig. 9.—Photomicrograph of a section of the adrenal cortex (zona fasciculata) taken in the early period of development of shock (two and a half hours after severe freeze). Notice the prominent infiltration of polymorphonuclear neutrophilic leukocytes.

Fig. 10.—Photomicrograph of a section of skeletal muscle (lower extremity, site of freeze) taken in the early period of development of shock (two and a half hours after severe freeze). Notice the prominent dilatation of capillaries with the packing of masses of red blood cells (stasis) and the edema causing a spreading of the muscle fibers. An occasional neutrophilic leukocyte is seen in an interstitial location.

a more rapid loss the final determination of plasma volume gives a result that tallies close to that expected when no endothelial damage exists. Table 3 exemplifies this point. The concentration of the dye was recorded at various intervals during the control period and after the animal was in deep and late shock.

The blue dye method, then, seems to serve as a good index of the degree of decrease of plasma volume, and at the same time it serves as a means of estimating the amount of total protein lost from the circulation during freezing shock.

The two methods that have been used to determine changes in the amount of extracellular water are the thiocyanate method and the determination of the plasma sodium concentration. The latter is made possible by the concept that the sodium ion does not pass through

TABLE 3.—*Concentration of Dye in a Dog at Various Intervals During Control and Shock Periods* *

Dog	Weight, Kg.	Period	Minutes After Injection	Plasma Volume, Cc.	Blood Pressure, Mm. of Hg	Concentration of Dye, Mg./100 Cc.
278	10	Control	10	600	165	0.91
		Control	24	...	...	0.91
		Control	41	...	...	0.85
		Shock	10	291	78	2.06
		Shock	19	...	73	2.06
		Shock	30	...	60	1.97

* Note that there is no perceptible difference in the concentration of blue dye for ten to fourteen minutes after thorough mixing. The disappearance of the dye from the plasma is more rapid during shock. On each occasion (control and shock) 6 mg. of Evans' blue dye was injected intravenously.

cellular membranes.[19] In an acute experiment an increase in sodium ion concentration is taken to represent a loss of water from the extracellular compartment without a corresponding loss of sodium. It is not known as yet how valid the thiocyanate method is in severe and late shock. It appears logical to assume that if the changes in sodium ion concentration correspond to the results obtained by the thiocyanate method the latter method is as dependable in late shock as in normal or near-normal circulatory conditions. Such a correlation has been observed in these studies.

It is evident that these tests have at present a somewhat ill defined status, and one may be hesitant to draw clearcut conclusions from them, but they at least serve to indicate qualitative trends. These trends

19. Gilman, A.: Experimental Sodium Loss Analogous to Adrenal Insufficiency: The Resulting Water Shift and Sensitivity to Hemorrhage, Am. J. Physiol. **108**:662-669 (June) 1934. Peters, J. J.: Water Balance in Health and in Disease, in Duncan, G. G.: Diseases of Metabolism, Philadelphia, W. B. Saunders Company, 1942, chap. 6, pp. 270-350.

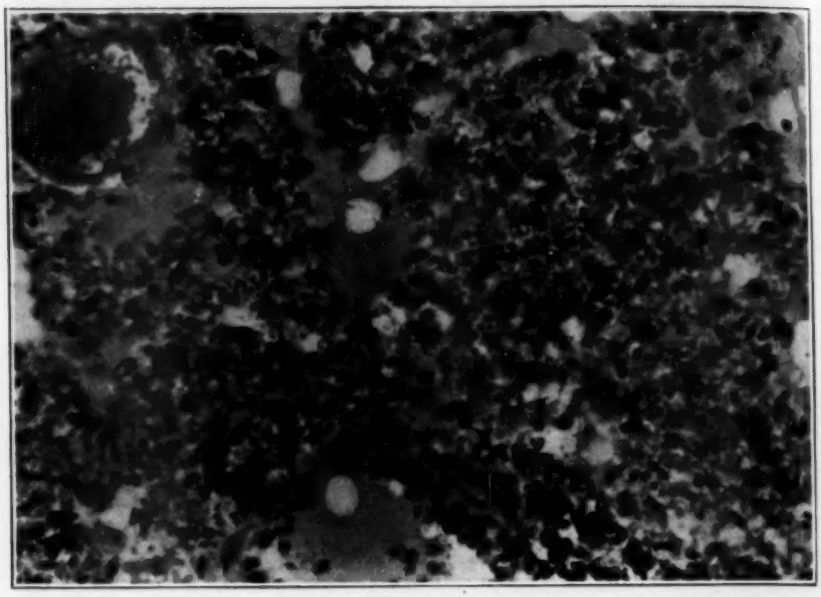

Fig. 11.—Photomicrograph of a section of a lung taken during shock (late period) over four hours after severe freeze. Marked capillariovenous hyperemia, capillary hemorrhages and edema are present.

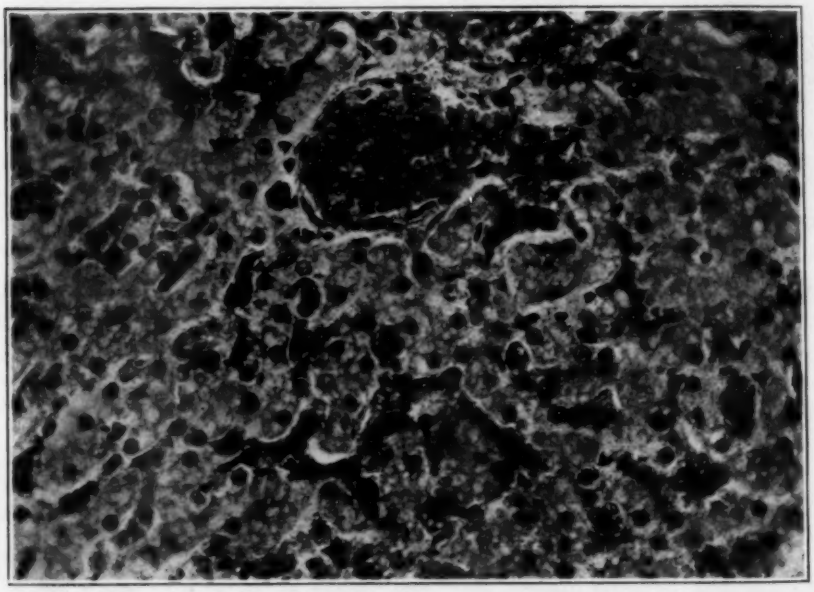

Fig. 12.—Photomicrograph of a section of the liver (near central vein) taken during shock (late period) over four hours after severe freeze. Marked veno-sinusoidal hyperemia and droplet degeneration of cytoplasm are present.

suggest that in late freezing shock there are a pronounced decrease in plasma volume, a pronounced decrease in total circulating protein and a decrease in both the extracellular and the interstitial fluid volume. It would also seem logical to assume that the decrease in extracellular volume results from the passage of water into body cells, since no other easily accessible reservoir is available. In a future publication [5] data indicating that this misplaced water is available for increase in plasma volume following treatment with concentrated protein solutions will be discussed.

The samples of plasma taken for study after the freeze were invariably stained with free hemoglobin. The staining was greatest

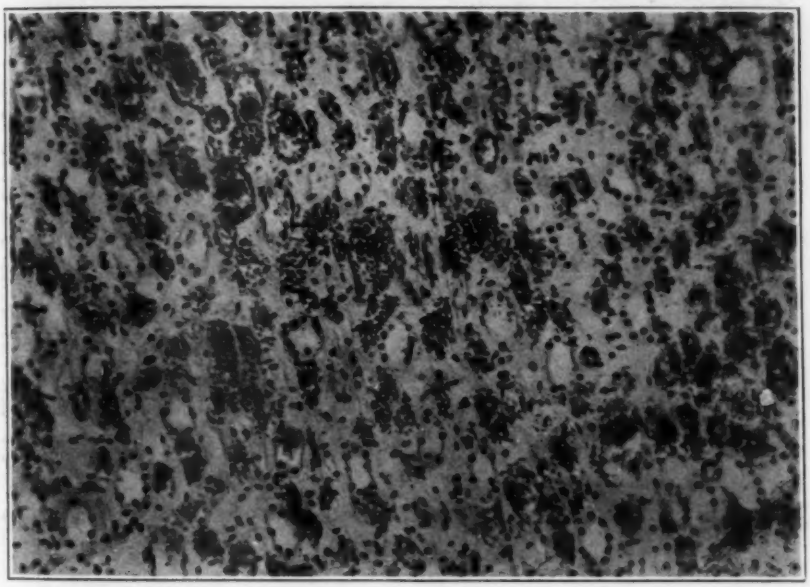

Fig. 13.—Photomicrograph of a section of the kidney (medulla) taken during shock (late period) over four hours after freeze. There is marked capillary hyperemia.

during deep and late shock. Control samples never revealed such staining. When determinations of plasma hemoglobin [20] were carried out, it was observed that the hemoglobin concentration remained the same at intervals of several minutes over a period of one hour. It was also noticed that the control sample for the determination with Evans' blue dye could be set at 100 in the colorimeter and that samples taken

20. Bing, F. C., and Baker, R. W.: The Determination of Hemoglobin in Minute Amounts of Blood by Wu's Method, J. Biol. Chem. **92**:589-600 (Aug.) 1931.

after the injection of the dye could be read as usual in the photoelectric colorimeter without the need for using special filters and equations such as are commonly employed to correct for the effects of the staining of the plasma with hemoglobin.

The liberation of free hemoglobin did not seem to be due to the breaking up of fragile cells as they were jammed into the narrow orifice of the venipuncture needle. This was demonstrated when hemoglobin-containing plasma was obtained by bleeding from the carotid artery directly into a test tube and immediately centrifuging the sample.

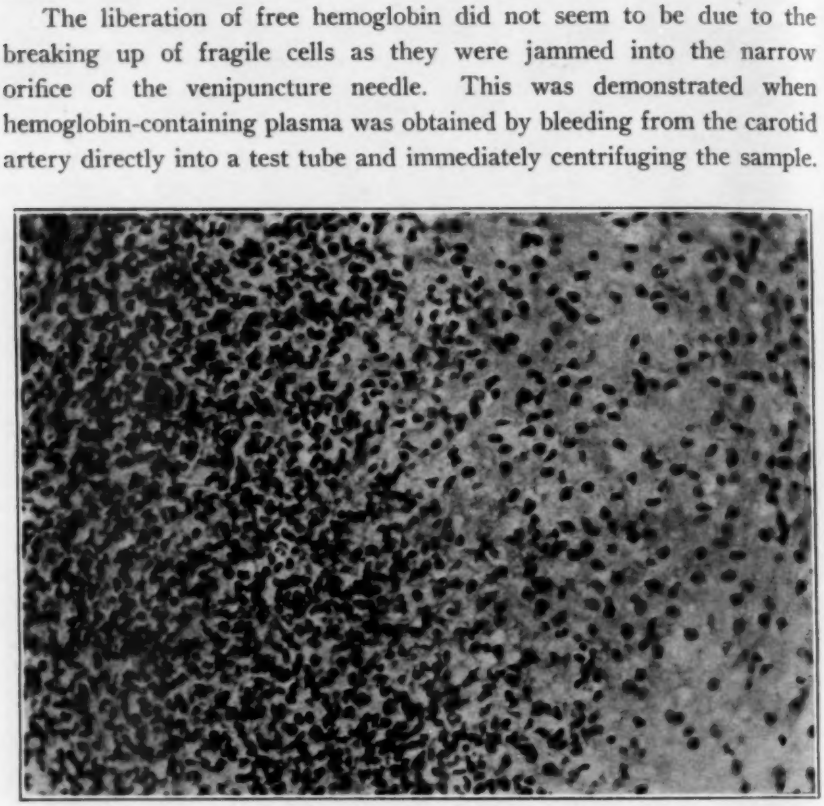

Fig. 14.—Photomicrograph of a section of the adrenal cortex (zona fasciculata) taken during shock (late period) over four hours after severe freeze. There is necrosis of the zona fasciculata with a bordering zone of leukocytic infiltration.

It was considered, then, that hemoglobinemia occurred after the freeze. The most logical source seemed to be the frozen limb, since one of the most rapid methods of artificially producing hemolysis is by freezing and thawing whole blood in vitro. Since the apparent hemoglobinemia was greatest during the late phase of shock and since it had been observed by us in traumatic shock, it was considered that other factors operated to produce an intravascular liberation of hemoglobin from red blood cells. Whether the element of stasis within capillaries during shock is conducive to this phenomenon can be considered only through reasoning by analogy. Stasis of red blood cells in the spleen

has been considered to produce spheroidicity, increased fragility and possible in vivo hemolysis.[21] Coonse, Foisie, Robertson and Aufranc [22] also observed in vivo hemolysis during traumatic shock in animals.

The pathologic changes seen microscopically were compared with observations on control animals subjected to uncomplicated soluble pentobarbital anesthesia and on controls killed by a fatal hemorrhage after a few minutes of deep ether anesthesia. Blalock [23] discussed the histologic changes following prolonged periods of various types of experimental anesthesia. Such changes resemble in certain respects the vascular manifestations in late shock. Moon [24] emphasized the role of

Fig. 15.—Photomicrograph of a section of skeletal muscle (lower extremity, site of freeze) taken during shock (late period) over four hours after freeze. Marked capillary and venous stasis, edema and necrosis of muscle fiber. Notice the close resemblance to figure 10.

21. Ham, T. H., and Castle, W. B.: Studies on Destruction of Red Blood Cells: Relation of Increased Hypotonic Fragility and of Erythrostasis to the Mechanism of Hemolysis in Certain Anemias, Proc. Am. Phil. Soc. **82**:411-419 (May) 1940; abstracted in Minot, G. R., and Castle, W. B.: Year Book of General Medicine, Chicago, The Year Book Publishers, Inc., 1940, pp. 365-367.

22. Coonse, G. K.; Foisie, P. S.; Robertson, H. F., and Aufranc, O. E.: Traumatic and Hemorrhagic Shock: Experimental and Clinical Study, New England J. Med. **212**:647-663 (April 11) 1935.

23. Blalock, A.: Shock: Further Studies with Particular Reference to Effects of Hemorrhage, Arch. Surg. **29**:837-857 (Nov.) 1934.

24. Moon, V. H.: Shock and Related Capillary Phenomena, New York, Oxford University Press, 1938.

anesthetic agents in modifying the late pathologic changes caused by shock. In our present studies we feel justified in separating the early from the late observations because the differences were so clearcut. The fact that the early vascular changes and those of the anesthesia control dogs resembled each other is further evidence in favor of the meagerness or absence of generalized capillariovenous changes during the period of greatest loss of plasma. Since normal dogs invariably recover successfully from the doses of soluble pentobarbital used in the present studies and since following freezing there was invariably progressive and fatal shock, the pathologic changes of the late period must have been due to the shock and its complications.

COMMENT

In these studies on shock following freezing (thermal injury) there was a difference between the period of greatest loss of plasma and the period of marked damage to the capillaries and tissues. This is in accord with the observations on the thermal injury due to burns recorded by Dunphy, Gibson and Keeley.[16] However, as was pointed out by these authors, it does not mean that under different circumstances shock cannot be due to generalized capillary (endothelial) damage. Moon [25] demonstrated that deficit of blood volume with hemoconcentration associated with certain toxic agents (such as histamine) is the result of generalized loss of plasma through damaged capillaries. Nevertheless, when the local damage is such as to give rise to a rapid local loss of plasma without any complicatnig hemorrhage, the generalized damage to capillaries and tissues seems to be secondary. The latter events occur after a severe freeze and are concordant with the contentions of Blalock [26] concerning other shock-producing injuries associated with prominent local loss of fluid.

It has been confusing to us in the past to observe waning hemoconcentration during the period when damage to the capillaries was supposedly greatest (late shock). In these studies, this definite stabilization of hemoconcentration (loss of plasma) was directly related to the interval when the peripheral arterial blood pressure dropped. This correlation has led to the conclusion that the hydrostatic pressure in the capillaries was insufficient to force plasma out in spite of severe damage to the capillaries. Tension in the tissues at the site of the freeze may influence the loss of plasma in the later periods. That this

25. Moon, V. H.: The Vascular and Cellular Dynamics of Shock, Am. J. M. Sc. **203**:1-18 (Jan.) 1942; footnote 24.

26. Blalock, A.: Principles of Surgical Care: Shock and Other Problems, St. Louis, C. V. Mosby Company, 1940.

is not the only factor involved, however, is demonstrated by the increase in weight and size of the damaged limb following therapy with solutions of sodium chloride or with dilute serum.[5]

After hemorrhage the blood volume may be adequately maintained by the passage of fluid from the tissues (interstitial and/or cellular compartments) into the blood stream.[27] Moon and associates [28] demonstrated outstanding hemodilution and a decrease of the fluid content of certain tissues in the body when large volumes of blood were removed from dogs over periods up to fifty-four hours. On the other hand, if the blood volume is allowed to remain sufficiently depleted over a period of a few hours by repeated bleedings alone, hemoconcentration [29] and damage to the capillaries can occur.[30] The degree of hemoconcentration may be influenced by the hydrostatic pressure in the capillaries at the time when the endothelial damage is sufficient to allow the escape of plasma.

The loss of plasma with hemoconcentration associated with large hemorrhages does not seem to be so much dependent on how long the blood pressure is depressed or how much blood is removed as on how long the circulating blood volume is allowed to remain critically depleted. Therefore, if after each bleeding sufficient time is allowed for the inrushing tissue fluid to swell the blood volume above the critical level, hemoconcentration and shock need not develop at all, but instead outstanding hemodilution will result.

The foregoing analysis is once more presented to emphasize the necessity of the maintenance of the circulating volume in the treatment of shock rather than the maintenance of any particular constituent of blood, such as the red blood cells. Similarly, prevention of hemorrhagic

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27. (*a*) Adolph, E. F.; Gerbon, M. J., and Lepore, M. J.: The Rate of Entrance of Fluid into the Blood in Hemorrhage, Am. J. Physiol. **104**:502-517 (May) 1933. (*b*) Stewart, J. D., and Rourke, G. M.: Intracellular Fluid Loss in Hemorrhage, J. Clin. Investigation **15**:697-702 (Nov.) 1936. (*c*) Lands, A. M., and Johnson, W.: Distribution of Body Water Following Hemorrhage, Proc. Soc. Exper. Biol. & Med. **49**:123-128 (Feb.) 1942.

28. Moon, V. H.; Morgan, D. R.; Lieber, M. M., and McGrew, D.: Similarities and Distinctions Between Shock and the Effects of Hemorrhage, J. A. M. A. **117**:2024-2030 (Dec. 13) 1941.

29. (*a*) Blalock, A.: Acute Circulatory Failure as Exemplified by Shock and Hemorrhage, Surg., Gynec. & Obst. **58**:551-566 (March) 1934. (*b*) Davis, H. A., cited by Harkins.[30] (*c*) Muirhead, E. E.; Ashworth, C. T., and Hill, J. M.: The Therapy of Shock in Experimental Animals wtih Plasma Protein Solutions: I. Concentrated Plasma as a Hemodiluting Agent, Surgery **12**:14-23 (July) 1942.

30. Harkins, H. W.: Recent Advances in the Study and Management of Traumatic Shock, Surgery **9**:231-294 (Feb.) 1941. Blalock.[29a] Davis.[29b]

shock with extreme hemodilution can be accomplished by the proper use of solutions of concentrated plasma [31] with practically no risk of critical anemic anoxemia.

The importance of the depleted blood volume,[32] the decreased venous return to the heart and central effective venous pressure,[33] the decreased cardiac output,[34] the alterations of peripheral blood flow [35] and other changes in hemodynamics associated with shock have been justly emphasized. It appears that insufficient emphasis has been placed on the possible abnormal shifts of fluid between the plasma, interstitial and cellular fluid compartments in shock and during its pathogenesis. This is surprising, since Moon [36] observed an increase in the fluid content of tissue during shock and Davis [37] noted that the viscera weighed more when patients died after a period of shock. Ashworth and Kregel [38] observed abnormalities in distribution of fluid and in electrolytic balance associated with posthemorrhagic shock and with shock following the intraperitoneal injection of hypertonic solution of sodium chloride. In the severe posthemorrhagic type the interstitial fluid volume decreased, and this was considered to be due to the shifting of fluid into an abnormal location, such as body cells. In the other type of shock an increase in interstitial fluid was observed. This was interpreted to represent a pronounced increase in concentration of extracellular sodium which caused a shift of fluid out of body cells. The present study on freezing shock indicates not only a decrease in plasma

31. (*a*) Hill, J. M.; Muirhead, E. E.; Ashworth, C. T., and Tigertt, W. D.: The Use of Desiccated Plasma with Particular Reference to Shock, J. A. M. A. **116**:395-402 (Feb. 1) 1941. (*b*) Muirhead, E. E., and Hill, J. M.: The Advantages and Clinical Uses of Desiccated Plasma Prepared by the Adtevac Process, Ann. Int. Med. **16**:286-302 (Feb.) 1942.

32. Keith, N. M.: Blood Volume Changes in Wound Shock and Primary Hemorrhage, Medical Research Committee, Special Report Series, no. 27, London, His Majesty's Stationery Office, 1919.

33. Wiggers, C. J.: The Present Status of the Shock Problem, Physiol. Rev. **22**:74-123 (Jan.) 1942.

34. Johnson, G. S., and Blalock, A.: Experimental Shock: Study of Effects of Hemorrhage, of Trauma to Muscles, of Trauma to Intestines, of Burns and of Histamine on Cardiac Output and on Blood Pressure of Dogs, Arch. Surg. **23**:855-863 (Nov.) 1931.

35. Cullen, M. L.; Schecter, A. E.; Freeman, N. E., and Laws, M. K.: The Circulation in Traumatic Shock, in Mudd, S., and Thalhimer, W.: Blood Substitutes and Blood Transfusion, Springfield, Ill., Charles C. Thomas, Publisher, 1942.

36. Moon (footnotes 24 and 25).

37. Davis, H. A.: Pathology of Shock in Man: Visceral Effects of Trauma, Hemorrhage, Burns and Surgical Operations, Arch. Surg. **41**:123-146 (July) 1940.

38. Ashworth, C. T., and Kregel, L. A.: Changes in the Body Water Partition and Extracellular Electrolytes in Shock, Arch. Surg. **44**:829-839 (May) 1942.

but also a depletion of the interstitial fluid, which seems to suggest a shift of fluid into cells, particularly in the late phases of such shock. Such changes are important because they are directly related to the treatment of shock. It is generally agreed that proper intravenous administration of fluid offers more in the prevention and the treatment of shock than any other single procedure. The intravenous injection of a solution that instead of remaining within blood vessels passes into the tissues merely accentuates the abnormal distribution of fluid present. Conversely, a solution capable of shifting the misplaced fluid into the blood stream and retaining it there not only increases a depleted blood volume but at the same time reverses one of the abnormalities present. There are indications that in normal animals concentrated serum is capable of mobilizing cellular fluid.[39] Evidence supporting the occurrence of a similar shift in late freezing shock will be presented later.[5]

In the histologic observations made in the present study outstanding lesions were related to the adrenal cortex, particularly the zona fasciculata. Such lesions have been emphasized by Dunphy, Gibson and Keeley [16] and others.[40] The former authors reported slight but similar changes in the adrenal cortex following anesthesia induced with soluble pentobarbital. We have been unable to observe such changes after one and one-half and two and one-half hours of similar anesthesia. The role of the lesions in the adrenal cortex in the shock syndrome is not known. Adrenal cortical extract has been administered in cases of shock, partly because such lesions have been observed, partly because of its apparent action on endothelial permeability and tone of the capillaries and partly because of the elevation in the potassium content of the plasma in the late phase of shock. The effect of the synthetic preparation desoxycorticosterone acetate on capillary permeability has been questioned.[41] However, clinically, beneficial results have been observed from the use of cortical extract.[42] Certain questions concerning this problem require reexamination. First, is the possible decrease in distribution of the hormone of the adrenal cortex due to

39. Ashworth, C. T.; Muirhead, E. E., and Hill, J. M.: The Effect of Hypertonic Plasma on the Body Fluids in Normal Experimental Animals, Am. J. Physiol. **136**:194-199 (March) 1942.

40. Davis, H. A.: Pathology of Dehydration Shock, Arch. Surg. **42**:939-955 (May) 1941. Duncan, G. W., and Blalock, A.: The Uniform Production of Experimental Shock by Crush Injury: Possible Relationship to Clinical Crush Syndrome, Ann. Surg. **115**:684-697 (April) 1942. Davis.[37]

41. Fine, J., and Fischmann, J.: A Study of the Effect of Desoxycorticosterone Acetate on Capillary Permeability, Proc. Soc. Exper. Biol. & Med. **49**:98-102 (Jan.) 1942.

42. Rhoads, J. E.; Wolff, W. A., and Lee, W. E.: The Use of Adrenal Cortical Extract in the Treatment of Traumatic Shock of Burns, Ann. Surg. **113**:955-968 (June) 1941.

a decrease in its production as indicated by the cortical lesions, or is it due to a lack of distribution attended by a stagnant circulation? Second, are the beneficial results produced by administration of adrenal cortical extract due not only to its action on endothelial permeability and capillary tone but also to its influence on cellular water? It has been considered that in the crisis of Addison's disease (clinical or experimentally produced) there is a shift of water into cells which is reversed when adrenal cortical extract is administered. If such questions were answered, this treatment for shock might be established on a firmer basis.

SUMMARY AND CONCLUSIONS

A severe freeze of one entire hindlimb of a dog is a reliable and simple method of producing a rapid and pronounced loss of plasma volume (blood volume) in an experimental animal without complicating hemorrhages. Thawing is complete in one to one and one-half hours at room temperature, and the procedure leads regularly to severe and fatal shock within six to twelve hours.

The greatest loss of plasma volume occurred within the two and one-half hours immediately following the freeze (early period). This was the interval when generalized damage to the capillaries of the viscera was mild or absent and did not differ materially from the slight dilatation of the capillaries occasionally observed during the same interval in animals under uncomplicated anesthesia induced with soluble pentobarbital U. S. P. (pentobarbital sodium). Generalized interstitial and cellular changes were not observed to occur in this period.

During this early period the only outstanding pathologic changes were in the frozen and thawed limb and in the adrenal cortex (zona fasciculata). The early lesions in the latter were a decrease in lipid content and prominent infiltration by polymorphonuclear neutrophilic leukocytes.

After the fourth hour (late period) the loss of plasma decreased greatly, but generalized capillariovenous dilatation was marked. In this interval pulmonary edema, capillary hemorrhages, leukocytosis and cellular changes in parenchymatous organs became evident.

The stabilization of the hemoconcentration in spite of evidences of generalized damage to the capillaries was directly associated in time with the drop in the peripheral arterial pressure.

Studies on hemoconcentration, plasma volume, total circulating proteins, carbon dioxide–combining power of the plasma, water available for the solution of sodium thiocyanate and plasma sodium concentration gave rise to certain interesting observations. There was an extreme depletion of plasma volume and total circulating proteins, which was paralleled by the hemoconcentration. The carbon dioxide–combining

power of the plasma was greatly decreased. The water available for the solution of thiocyanate (extracellular) was decreased, with a corresponding increase in plasma sodium concentration. In view of the observations by others suggesting an increase in tissue fluids in other forms of shock, these two findings are interpreted as representing the passage of water into body cells.

On the basis of definite staining of the samples of plasma with hemoglobin, hemoglobinemia was considered to be present. The possible causes for this phenomenon are discussed.

Certain therapeutic applications of these observations are presented.

The possible role of the hormone of the adrenal cortex and its theoretic relation to the changes produced by shock are briefly mentioned.

Miss Mary Seaman prepared all of the tissue sections (approximately 300 blocks) and Miss Frances Jones determined the carbon dioxide-combining power of the plasma. The other procedures were performed by us.

3301 Junius Street.

EXPERIMENTAL GAS GANGRENE

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AND
FRANK L. MELENEY, M.D.
NEW YORK

The purpose of this paper is to report a series of experiments with animals carried out in order to evaluate the effectiveness of the local application of certain of the newer chemotherapeutic agents in fresh traumatic wounds contaminated with the species of clostridia commonly associated with clinical gas gangrene in human beings.

While there are already considerable data along these lines, the results of the experiments reported in the literature have not been uniform, and there are differences of opinion among various observers as to the merit of chemotherapy in relation to the prevention and the treatment of these infections.

REVIEW OF THE LITERATURE

The first article dealing with the use of sulfonamide compounds in the treatment of gas gangrene in experimental animals was that of Domagk [1] in 1937. He produced gas gangrene in mice by the intramuscular injection of Clostridium septicum and treated the animals with certain of the sulfonamide compounds (sulfanilamide, sulfanilylsulfanilamide, sulfanilylmonomethylsulfanilamide, and sulfanilyldimethylsulfanilamide) given orally. Sulfanilamide was ineffective, but in some experiments with the other three compounds as high as 70 per cent of the treated animals survived. Domagk stated that with Clostridium welchii less favorable results were obtained. About the same time Long and Bliss [2] reported that they were able to protect mice against intraperitoneal injection of Cl. welchii by means of oral administration of sulfanilamide commenced one hour after the injections. Of the treated animals 72 per cent survived, as compared with 7 per cent of the controls. Using mice,

From the Bacteriological Research Laboratory of the Department of Surgery, Columbia University College of Physicians and Surgeons.

1. Domagk, G.: Weitere Untersuchungen über die chemotherapeutische Wirkung sulfonamidhaltiger Verbindungen bei bakteriellen Infektionen, Klin. Wchnschr. **16**:1412-1418 (Oct. 9) 1937.

2. Long, P. H., and Bliss, E. A.: Observations upon the Experimental and Clinical Use of Sulphanilamide in the Treatment of Certain Infections, Canad. M. A. J. **37**:457-465 (Nov.) 1937.

Natvig [3] injected 0.1 cc. of twenty-four hour cultures of Cl. welchii, Clostridium histolyticum, Cl. septicum and Clostridium novyi intramuscularly into one buttock and different amounts of azosulfamide [4] into the other. No protection was observed. All of the treated as well as all of the control animals died from gas gangrene within one to two days. Another unfavorable report came from Kendrick,[5] who worked with guinea pigs and produced gas gangrene by the intramuscular injection of Cl. welchii. Sulfanilamide was administered by mouth, subcutaneously and intraperitoneally; azosulfamide was given subcutaneously, and sulfapyridine (2-[paraaminobenezenesulfonamido]-pyridine) was given by mouth. None of the drugs was found to be effective. On the other hand, considerable success was obtained by the use of antitoxin. Johnson and Meleney [6] studied the action in vivo of zinc peroxide on Cl. welchii. Organisms from an eighteen hour culture mixed with zinc peroxide suspension immediately before use were injected into the thigh muscles of guinea pigs. Of 18 animals thus treated 94 per cent survived, whereas none of the control animals survived.

Early in 1940 there appeared a succession of papers dealing with the chemotherapy of experimental gas gangrene. Stephenson and Ross [7] studied the effect of orally or subcutaneously administered sulfanilamide and sulfapyridine and antitoxic serum on Cl. welchii, Cl. septicum and Cl. novyi infections produced in mice by either intraperitoneal or intramuscular injections of suspensions of vegetative organisms in sterile garden soil. These authors concluded that when Cl. welchii was injected intraperitoneally sulfanilamide and sulfapyridine protected against a small number of lethal doses. On the other hand, when the injection was intramuscular, the drugs were of value only against a sublethal dose. In the animals inoculated intraperitoneally treatment with serum was effective for a strain of high toxigenicity but failed against a strain of low toxigenicity but higher invasiveness. For the group of animals given intramuscular injections serum treatment was better than drug therapy.

3. Natvig, H.: Experimental Investigations on Effect of Prontosil in Gas Gangrene, Norsk mag. f. lægevidensk. **99**:631-635 (June) 1938.

4. Azosulfamide is disodium-4-sulfamidophenyl-2′-azo-7′-acetylamino-1′-hydroxynaphthalene-3′,6′-disulfonate. This substance has been known as prontosil soluble, as prontosil and as neoprontosil.

5. Kendrick, D. B., Jr.: Treatment of Gas Gangrene Infections in Guinea Pigs with Neoprontosil, Sulfanilamide, and Sulfapyridine: An Experimental Study, J. Clin. Investigation **18**:593-596 (Sept.) 1939.

6. Johnson, B. A., and Meleney, F. L.: The Antiseptic and Detoxifying Action of Zinc Peroxide on Certain Surgical Aerobic, Anaerobic, and Micro-Aerophilic Bacteria, Ann. Surg. **109**:881-911 (June) 1939.

7. Stephenson, D., and Ross, H. E.: The Chemotherapy of Cl. Welchii Type A and Cl. Septique Infections in Mice, Brit. M. J. **1**:471-475 (March 23) 1940.

Sulfanilamide had little influence on infections produced with Cl. septicum. Sulfapyridine was better and in large doses saved 50 per cent of the animals. Treatment with a single dose of antitoxic serum was at least as effective as sulfapyridine. However, the best results were obtained by a combination of sulfapyridine and serum. Neither of the drugs had any influence on the course of infection with Cl. novyi. Henderson and Gorer [8] found that sulfapyridine by mouth was effective when vegetative forms of Cl. welchii or spores of Cl. septicum were introduced into mice by intradermal injection but that it was unreliable against intramuscular injections. The results against Cl. welchii were much less striking than those against Cl. septicum. Sulfanilamide was found to be markedly inferior to sulfapyridine. These observers were also able to show that Cl. septicum antitoxin and antibacterial serum and Cl. welchii antitoxin given intravenously were superior to sulfapyridine given by mouth. In intradermal injection with Cl. septicum the combined action of sulfapyridine and antitoxin or of sulfapyridine and antibacterial serum was shown under the conditions of their experiment to be more effective than any one of the agents alone. Morales-Otero and Gonzalez [9] reported that they were unable to protect mice from 1 minimal lethal dose of Cl. welchii by simultaneous intramuscular injection of azosulfamide.

Penicillin as a chemotherapeutic agent in the treatment of experimental gas gangrene infections was reported on by a group of British observers [10] in 1940. These workers injected Cl. septicum spore suspensions intramuscularly into mice, and when subcutaneous therapy was begun one hour after injection and large doses of penicillin were repeated for several days, excellent results were obtained.

Singer [11] studied the effect of the oral administration of certain sulfonamide compounds (sulfanilamide, sulfapyridine, dimethyldisulfanilamide and soluseptasine [disodium *p*-(γ-phenylpropylamino)-benzenesulfonamido-a-γ-disulfonate]) on mice inoculated subcutaneously with Cl. welchii, Cl. septicum and Cl. novyi. When 1 minimal lethal dose of Cl. welchii was used, good results were obtained. However, when multiples of 1 minimal lethal dose were used, some mice survived, but

8. Henderson, D. W., and Gorer, P. A.: The Treatment of Certain Experimental Anaerobic Infections with Sulphapyridine and Immune Sera and the Problem of Synergistic Action, J. Hyg. **40**:345-364 (May) 1940.

9. Morales-Otero, P., and Gonzalez, L. M.: Effect of Azosulfamide (Neoprontosil) in Experimental Welchii Infections in Mice, Proc. Soc. Exper. Biol. & Med. **44**:532-534 (June) 1940.

10. Chain, E.; Jennings, M. A.; Florey, H. W.; Orr-Ewing, J.; Gardner, A. D., Sanders, A. G., and Heatley, N. G.: Penicillin as a Chemotherapeutic Agent, Lancet **2**:226-228 (Aug. 24) 1940.

11. Singer, E.: A Note on the Treatment of Gas Gangrene with Sulfanilamide and Related Compounds, M. J. Australia **1**:796-799 (June 8) 1940.

the majority were not saved. In Cl. septicum infections protection was obtained only with sulfapyridine, and in infections with Cl. novyi complete failure was encountered. In a subsequent paper Singer [12] reported that by using small amounts of antitoxic serum in Cl. welchii and Cl. septicum infections he was able to reduce the dose of sulfanilamide or of its derivatives needed to protect the mice.

In 1941 Longacre and Honold [13] reported studies in which they injected Cl. welchii intramuscularly in guinea pigs and administered sulfanilamide and derivatives of it intraperitoneally. They found that sulfanilamide and sulfapyridine were of little benefit and in no way modified the course of the infection. Although in animals treated with sulfamethylthiazole (2-[paraaminobenzenesulfonamido]-4-methyl-thiazole) and sulfathiazole (2-[paraaminobenzenesulfonamido]-thiazole) gas gangrene developed and death followed, the infection was delayed and in many instances was less extensive.

Producing Cl. welchii infections in pigeons, Erb and Hodes [14] studied the relative therapeutic value of sulfanilamide, specific serum and radiation. Their results indicated that in the pigeon sulfanilamide and roentgen radiation were valueless. Serum alone proved beneficial.

McIntosh and Selbie [15] carried out studies using Cl. welchii, Cl. septicum and Cl. novyi for the organisms and sulfanilamide, sulfapyridine and sulfathiazole for the treatment. Mice were given intramuscular injections, and the organisms and the agents were administered simultaneously. The results were expressed in terms of the average number of days that the animals survived rather than on a basis of whether or not the animals lived or died, and unfortunately mortality beyond a three day period was not recorded in the report. On the whole, with local therapy all three drugs were of value in delaying death. Against Cl. welchii the three agents were of value in essentially equal degree. Against Cl. septicum sulfathiazole was strikingly superior; little effect was noted with the other agents. Against Cl. novyi good results were obtained with sulfathiazole, which again was superior to the other

12. Singer, E.: Experimental Studies on the Combined Sulphanilamide and Serum Treatment of Gas Gangrene Infections, M. J. Australia **2**:275-279 (Sept. 28) 1940.

13. Longacre, A. B., and Honold, E.: Sulfanilamide, Sulfapyridine, Sulfathiazole and Sulfamethyl-Thiazole in Experimental Gas Gangrene in Guinea Pigs, Proc. Soc. Exper. Biol. & Med. **46**:9-14 (Jan.) 1941.

14. Erb, W. H., and Hodes, P. J.: Therapeutic Results of Various Forms of Treatment in Experimentally Produced Gas Gangrene, to be published; cited by Pendergrass, E. P., and Hodes, P. J.: Roentgen Irradiation in Treatment of Inflammations, Am. J. Roentgenol. **45**:74-106 (Jan.) 1941.

15. McIntosh, J., and Selbie, F. R.: Chemotherapy of Gas Gangrene, Lancet **1**:240-242 (Feb. 22) 1941.

agents. Oral administration of the drugs resulted in almost complete failure, and the combined oral and local route offered no more than the local route alone.

A comparison of the effectiveness of sulfanilamide, sulfapyridine and paranitrobenzenesulfonamide with serum was made by Gordon and McLeod.[16] Mice and guinea pigs were inoculated subcutaneously with Cl. welchii, Cl. septicum and Cl. novyi. Serum when administered locally prior to the injection of the organisms was 100 per cent effective in preventing death of the animals from gas gangrene due to each of the three organisms. Under the same conditions the same degree of effectiveness was attained against Cl. welchii with sulfapyridine. However, this drug showed limited effectiveness against Cl. septicum. Sulfanilamide likewise showed some value against Cl. welchii but failed to protect against the other two organisms. Paranitrobenzenesulfonamide was of practically no value. None of the agents were effective when administered locally four and seven hours after inoculation with the organisms.

In 1941 Ozorio de Almeida and Pacheco[17] reported that favorable results were obtained when guinea pigs given subcutaneous injections of cultures of Cl. septicum were placed two hours after injection in an oxygen chamber. Pressure as high as 5 atmospheres of oxygen (3,800 mm. of mercury) was maintained, and the best results were obtained when the animals were kept in the chamber for repeated periods of one hour. These workers were not able to extend their favorable results to infections with Cl. welchii and Cl. novyi, nor were they able to obtain any therapeutic effect when solutions of sodium perborate were injected locally, intraperitoneally or intravenously.

Armstrong and Rae[18] produced gas gangrene by injecting washed cultures of Cl. welchii suspended in calcium chloride solution into the muscles of guinea pigs. One hour later they injected sulfanilamide, sulfapyridine, sulfathiazole and *P*-tolylamidine hydrochloride into the original site of injection. This method saved a high percentage of animals. Oral administration was found to be ineffective.

Bliss, Long and Smith,[19] using mice and inoculating cultures of Cl. welchii and suspensions of spores of Cl. novyi and Cl. septicum

16. Gordon, J., and McLeod, J. W.: Relative Value of Sulfonamides and Antisera in Experimental Gas Gangrene, Lancet **1**:407-409 (March 29) 1941.

17. Ozorio de Almeida, A., and Pacheco, G.: Ensaios de tratamento das Gangrenas gazosas experimentais pelo oxigenio em altas pressoes e pelo oxigenio em estado nascente, Rev. brasil. de biol. **1**:1-10 (April) 1941.

18. Armstrong, A. R., and Rae, M. V.: Chemotherapy and Experimental Gas Gangrene, Canad. M. A. J. **45**:116-118 (Aug.) 1941.

19. Bliss, E. A.; Long, P. H., and Smith, D. G.: Chemotherapy in Experimental Gas Gangrene and Tetanus Infection in Mice, War Med. **1**:799-810 (Nov.) 1941.

intramuscularly simultaneously with various chemotherapeutic agents (sulfanilamide, sulfapyridine, sulfathiazole, sulfadiazine [2-(paraaminobenzenesulfonamido)-pyrimidine], sulfaguanidine [sulfanilylguanidine] and zinc peroxide), obtained favorable results with some of the drugs. Sulfadiazine was the most effective agent against Cl. welchii and Cl. septicum. Sulfathiazole was second best against the former and zinc peroxide against the latter. Contrary to their earlier report of success with sulfanilamide following intraperitoneal injection of Cl. welchii already noted, these authors found sulfanilamide to be valueless against intramuscular inoculation. It was also ineffective against Cl. septicum. Sulfaguanidine also was ineffective against these two organisms. Sulfapyridine was of some value against Cl. septicum but of no value against Cl. welchii. In the treatment of the animals inoculated with Cl. novyi the sulfonamide compounds used were valueless; on the other hand, zinc peroxide was effective in preventing death. The oral use of even the better agents was found to be inferior to local administration.

Sewell, Dowdy and Vincent [20] produced experimental gas gangrene in dogs by means of intramuscular injections of Cl. welchii. The therapeutic effects of roentgen radiation, sulfadiazine and a combination of the two were compared. The prophylactic effects of sulfadiazine, sulfanilamide and butyrylsulfanilamide were likewise studied. For prophylactic purposes the drugs were administered so that the blood concentration was raised to therapeutic levels prior to inoculation of the organisms. Sulfadiazine thus used protected 88 per cent of the animals, compared with a 16 per cent recovery rate for the controls. Sulfanilamide and butyrylsulfanilamide were definitely inferior to sulfadiazine. When chemotherapy was started after the infection was established, sulfadiazine protected only 28 per cent, compared with a 6.7 per cent recovery among the controls. Sulfadiazine was found to be superior to roentgen radiation alone and to roentgen radiation plus sulfadiazine. Of the animals receiving roentgen radiation therapeutically 26 per cent survived, compared with 17.9 per cent survival among the controls. The difference is not statistically significant.

It is to be noted that in all of the experiments referred to thus far the organisms were introduced by needle injection. What appears to us a well founded criticism of this method will be offered in a subsequent section.

The first experiments in which Clostridium-contaminated wounds were produced and treated with sulfonamide compounds applied locally were those reported by Legroux [21] in 1940. He attempted to reproduce

20. Sewell, R. L.; Dowdy, A. H., and Vincent, J. G.: Chemotherapy and Roentgen Radiation in Clostridium Welchii Infections, Surg., Gynec. & Obst. **74**:361-367 (Feb. 16) 1942.

21. Legroux, R.: Chimioprévention de l'infection bactérienne des plaies de guerre, Mém. Acad. de chir. **66**:415-424 (April 17-24) 1941.

war wounds in guinea pigs. He made thigh wounds, traumatized the muscle and produced contamination by adding a piece of cloth soaked with Cl. welchii or Cl. histolyticum. Sulfanilamide was dusted into the wounds at the time of contamination, and then the wounds were sutured. Animals thus treated lived from four to seven days, whereas the controls died within three days. If at the end of three days the wounds were reopened and more sulfanilamide was applied, the animals survived. Legroux found that if the drug was administered later than one hour after contamination treatment was ineffective. Likewise, oral administration of the drug was of no value.

Caldwell [22] produced traumatic wounds and compound fractures in guinea pigs, contaminated them with Cl. welchii and compared the effects of local and intraperitoneal administration of sulfanilamide, local application of zinc peroxide and roentgen therapy. In the wounds treated with sulfanilamide therapy was delayed one to six hours and was combined with debridement, after which the wounds were sutured. The results were poor; only 4 of 19 animals survived. Sulfanilamide administered intraperitoneally every six hours and combined with debridement and irrigation of the wounds two hours after contamination resulted in the survival of 7 of 9 animals. In another experiment debridement and irrigation and application of zinc peroxide were done two hours after contamination. The wounds were closed with suture material. Of 5 animals 4 survived. Roentgen radiation saved only 3 of 7 animals, but these results cannot be compared with those of the experiments with sulfanilamide and zinc peroxide since no debridement or irrigation was carried out.

Using a technic similar to that of Legroux, Hawking [23] carried out thorough studies on experimental gas gangrene in guinea pigs. He found that the application of sulfonamide compounds to the wounds at the same time as the insertion of the organisms saved a large proportion of the animals infected with Cl. welchii and with Cl. septicum but had slight influence on infections with Cl. novyi. Sulfanilamide was superior to sulfapyridine in preventing infection with Cl. welchii, but it had practically no activity against Cl. septicum. Sulfathiazole was the most effective compound used. Hawking compared the effect of delaying local treatment with sulfathiazole in 4 of his experiments with Cl. welchii and in one with Cl. septicum. Although the individual results were not indicated, he stated that taking the series as a whole he found that when treatment was immediate 67 per cent of the animals survived,

22. Caldwell, G. A.: Treatment of Gas Gangrene Experimentally Produced, J. Bone & Joint Surg. **23**:81-85 (Jan.) 1941.

23. Hawking, F.: Prevention of Gas Gangrene Infections in Experimental Wounds by the Local Application of Sulphonamide Compounds and by Sera, Brit. M. J. **1**:263-268 (Feb. 22) 1941.

that when treatment was delayed two hours 26 per cent survived and that when treatment was delayed six hours none of the animals survived. Local application of sulfathiazole to the wound was more effective in preventing death than intraperitoneal administration. Hawking also observed that the development of the infection in these wounds could be prevented by prophylactic administration of antitoxic serum. Monovalent serums specific for Cl. welchii, Cl. septicum or Cl. novyi protected the animals against these organisms respectively. A commercial polyvalent serum gave protection against most strains of Cl. welchii and Cl. novyi but not against Cl. septicum. In those instances in which serum was effective it was superior to sulfathiazole. In a subsequent study [24] Hawking compared sulfathiazole with sulfaguanidine and sulfadiazine and concluded that sulfaguanidine was definitely inferior to sulfathiazole while sulfadiazine was no better and probably inferior.

Bonnin and Fenner,[25] working under trying conditions in an army camp in Australia, carried out some interesting experiments, attempting to simulate war wounds as closely as possible. Wounds were produced in the muscles of guinea pigs; bone was also fractured. Into this traumatized tissue sterile garden soil was rubbed, and organisms were inserted. Sulfanilamide was the only drug used, and 0.5 Gm. of this was placed into the wound before closure. Twelve hours later the animals were reoperated on; complete excision of the damaged tissue was carried out, and the wounds were closed after the insertion of 1 Gm. of sulfanilamide. The results with Cl. welchii were good; with Cl. septicum, so far as survival was concerned, the results were not good, but there was definite prolongation of life. No success was obtained in the series of animals inoculated with Cl. novyi.

Reed and Orr [26] in a preliminary paper published in 1941 and in a subsequent one more recently [27] reported carrying out a thorough study in which a great number of experimental animals were used. In addition to the three species of Clostridium tested by most observers, a fourth, Clostridum sordellii, as well as a mixture of these with Clostridum sporogenes and Cl. histolyticum was used. Wounds were produced in guinea pigs in essentially the same manner as in the experiments of Legroux and others [28] and were closed with sutures. The chemo-

24. Hawking, F.: Sulphadiazine and Sulphanil-Guanidine Against Gas Gangrene, Brit. M. J. **2**:29-30 (July 5) 1941.

25. Bonnin, N. J., and Fenner, F.: Local Implantation of Sulphanilamide for Prevention and Treatment of Gas Gangrene in Heavily Contaminated Wounds: Suggested Treatment for War Wounds, M. J. Australia **1**:134-140 (Feb. 1) 1941.

26. Reed, G. B., and Orr, J. H.: Chemotherapy in Experimental Gas Gangrene, Lancet **1**:376-379 (March 22) 1941.

27. Reed, G. B., and Orr, J. H.: Local Chemotherapy of Experimental Gas Gangrene, War Med. **2**:59-78 (Jan.) 1942.

28. Caldwell.[22] Hawking.[23] Bonnin and Fenner.[25]

therapeutic agents were applied locally, both immediately after inoculation and after stated intervals. Oral therapy as well as a combination of local and oral therapy was also used. These observers concluded that the wounds contaminated with Cl. welchii responded most readily to chemotherapy, that those contaminated with Cl. septicum and Cl. novyi responded less well and that those contaminated with Cl. sordellii were much more resistant. With reference to the group of causative organisms as a whole, sulfathiazole was the most effective agent, sulfadiazine next and then followed sulfamethylthiazole, sulfapyridine, sulfaguanidine and sulfanilamide. Delay in instituting therapy was found to reduce the beneficial action of the drugs. Local treatment was found to be superior to oral. In another group of experiments [29] the effectiveness of zinc peroxide was studied. When the drug was applied immediately to wounds contaminated with Cl. welchii and Cl. novyi, all of the animals were saved. On the other hand, only half of the animals with Cl. septicum–contaminated wounds survived. Likewise, 50 per cent survival was obtained against the vegetative form of Cl. sordellii, yet against the spore form of this organism the recovery rate was increased to 80 per cent. Thus the results with zinc peroxide applied immediately compare favorably with those recorded for sulfathiazole. Delay in instituting therapy caused marked reduction in effectiveness, and here zinc peroxide was somewhat less effective than sulfathiazole.

This study of the literature has left us in a confused state of mind, and undoubtedly the reader of this brief review has been similarly affected. Usually when there is diversity of opinion with regard to any treatment, either there is an obvious reason for the variation in results, or the treatment is given undeserved credit for results due to other factors. Are there any obvious reasons why there is diversity of opinion relative to the value of chemotherapy in experimental gas gangrene? We believe there are.

Undoubtedly one of the reasons for some of the differences rests in the method used to produce the experimental lesion. Some observers injected the organisms subcutaneously; some injected them intramuscularly, while still others produced muscle wounds into which organisms were placed before closure. In some cases the needle injection of the bacteria was accompanied by muscle trauma, while in others no such trauma was introduced. Some authors reported adding to the organisms calcium chloride, and there were instances in which no lesion was produced in the absence of this chemical. Varying results can obviously be explained on the basis of differences in source as well as differences in virulence among the strains of organism used. With spore-producing

29. Reed, G. B., and Orr, J. H.: Treatment of Experimental Gas Gangrene with Zinc Peroxide, War Med. **2**:79-82 (Jan.) 1942.

and toxin-producing bacteria, such as the Clostridia, one has the choice of introducing either spores or vegetative forms with or without preformed toxin, and indeed all of these methods were used. That chemotherapy gives differing results with spores as against vegetative forms is borne out by some of the observations of Reed and Orr. The type of animal selected for experimentation and differences in dosages as well as in routes of administration are all additional reasons for variations in results which are sufficiently obvious to need no further elaboration.

On several important points there has been general agreement among the various reports. Most observers have expressed the opinion that chemotherapy is of some value in preventing experimental gas gangrene. Those who have compared serum with chemotherapy have stated that the former is more effective but that they have been impressed with the superiority of the combination over either alone. That local application of the chemotherapeutic agents is better than oral or parenteral administration has been accepted. Likewise the consensus is that Cl. novyi infections are refractory to the sulfonamide compounds. The only two observers who have used zinc peroxide against this organism have reported excellent results. Those who have worked with experimental roentgen radiation have been unanimous as to its lack of value. Just which of the sulfonamide compounds is best is unsettled. Most experiments have indicated that sulfadiazine and sulfathiazole are superior to the other sulfanilamide derivatives. In a later section some of the discrepancies as well as points of agreement will be pointed out in detail, and comparisons will be made with our own results.

EXPERIMENTAL PROCEDURES

In the experiments which are to be described in detail, wounds were produced in anesthetized guinea pigs and contaminated with certain of the Clostridia associated with gas gangrene in human beings. Subsequently these wounds were treated locally with certain of the newer chemotherapeutic agents for the purpose of evaluating the effectiveness of these agents in the prevention of experimental gas gangrene.

Cl. welchii (Clostridium perfringens), Cl. septicum (vibrion septique), Cl. novyi (Clostridium oedematiens) and Cl. sordellii (Clostridium oedematoides) were the organisms used. The first three are the Clostridia most commonly associated with clinical gas gangrene. The fourth, although not encountered as frequently as the other three, has also been reported as the causal agent of disease in human beings.[30] Two strains of Cl. welchii were used. The source of the strain used in experiment 1 is not clear; however, among several strains tested it proved to be the most pathogenic for guinea pigs. The strain used in experiment 2 had been isolated from a case of gas gangrene.[31] The other Clostridia were stock strains kept on hand in our own laboratory.

30. Humphreys, F. B.: Anaerobic Bacteria: The "Gas Gangrene" Group, in Gay, F. P., and others: Agents of Disease and Host Resistance, Springfield, Ill., Charles C. Thomas, Publisher, 1935, chap. 38.

31. This was furnished by Dr. F. B. Humphreys, of the Department of Bacteriology, Columbia University College of Physicians and Surgeons.

Cultures were grown in dextrose (0.2 per cent) cooked beef heart mediums for eighteen hours. (Four hour cultures were used in some wounds in experiment 3, and twenty-four hour cultures were used in experiment 4.) Cultures were tested for contamination by frequent platings. Titration of many of the cultures was carried out in order to estimate the number of organisms in each inoculum. The eighteen hour cultures of Cl. welchii contained not less than 10^9 organisms per cubic centimeter; those of Cl. septicum, not less than 10^8 organisms per cubic centimeter; and those of Cl. novyi, not less than 10^8 organisms per cubic centimeter. The four hour cultures on the whole contained correspondingly fewer organisms.

Experiments were carried out on 528 guinea pigs. Animals weighing from 250 to 300 Gm. (with an occasional larger or smaller one) were used. Throughout the period of postoperative observation the animals were kept separately in adequate-sized cages and were fed a diet consisting of oats and fresh green vegetables. On the whole they remained free from intercurrent infections.

The anesthetic agent (except for a few animals in experiment 3 on which open drop ether was used) was soluble pentobarbital. This was administered subcutaneously in the form of a 1 per cent solution in sterile distilled water. Four cubic centimeters of this solution per kilogram of body weight of the animal produced satisfactory anesthesia and lasted approximately four hours. Thus additional anesthesia was not required in those animals operated on a second time or treated following the first operation.

All of the wounds were produced in the posterior buttock (gluteal) region. This area was selected for the following reasons: 1. It provided a muscular region in which a soft tissue wound of the desired size could be readily produced. 2. It was a relatively immobile muscular area. 3. Dressings could be arranged over the wounds so that the animal could not disturb them. The hair over the area selected was clipped, and the skin was prepared with tincture of iodine. Sterile technic was used throughout. A standard type of dressing was adopted for initial as well as for subsequent dressings. This consisted of a small square of petrolatum gauze placed immediately over the wound and held in place by adhesive tape.

The chemotherapeutic agents[32] used in this study were as follows: sulfanilamide, sulfadiazine, sulfathiazole, sodium sulfadiazine, sodium sulfathiazole, gramicidin and zinc peroxide. The sulfonamide compounds were introduced directly into the wound in the dry state; zinc peroxide was used as a creamy suspension (the accepted method of clinical use), and gramicidin was applied as an alcoholic extract on saturated cotton so that it would remain in the wound. In each instance the quantity of drug used was based on the amount necessary to fill the wound and to maintain contact with all parts of it.

After each experiment the animals were carefully observed at frequent intervals. Those that died were submitted to autopsy. The pathologic appearance of the lesion produced by each species is characteristic and is described in another section. In many instances cultures were taken from the edema fluid and exudate and from the heart's blood. In almost every case these yielded growth of the organism used. Twenty-eight of the animals died from causes other than gas gangrene, such as pneumonia or gastroenteritis. Those dying without evidence of gas gangrene but living beyond the period during which gas gangrene would

32. Dr. René Dubos of the Rockefeller Institute provided the gramicidin; E. I. DuPont de Nemours and Company (Inc.) contributed the zinc peroxide, and Lederle Laboratories, Inc., supplied the other drugs used in this study.

have been expected to develop are for the purpose of this study classified as survivals.

Experiment 1.—An incision 0.5 cm. long was carried through the skin and the subcutaneous tissue down to the muscle, which was incised transversely. The resulting muscle incision was approximately 0.5 cm. wide and 0.5 cm. deep. The tissue on both margins of the incised muscle wound was crushed with a small hemostat. One-tenth cubic centimeter of an eighteen hour culture of Cl. welchii was placed into the wound. Dressing was applied. After two hours one group of

TABLE 1.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Welchii*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)
Controls	20	14	6	30
Debridement and irrigation only	10	8	2	20
Sulfanilamide	10	4	6	60
Sulfanilamide plus debridement and irrigation	10	0	10	100
Sulfadiazine	10	3	7	70
Sulfadiazine plus debridement and irrigation	10	3	7	70
Sodium sulfadiazine	10	2	8	80
Sodium sulfadiazine plus debridement and irrigation	10	2	8	80
Sulfathiazole	10	3	7	70
Sulfathiazole plus debridement and irrigation	10	2	8	80
Sodium sulfathiazole	10	2	8	80
Sodium sulfathiazole plus debridement and irrigation	10	0	10	100
Zinc peroxide	10	8	2	20
Zinc peroxide plus debridement and irrigation	10	4	6	60

TABLE 2.—*Summary of Recovery Rates After Local Chemotherapy in Wounds Contaminated with Cl. Welchii*

	Recovery Rates (Per Cent)
Controls	30
Debridement and irrigation	20
Chemotherapy alone	63
Chemotherapy plus debridement and irrigation	82

these animals was reoperated on. The skin incision was prolonged to double its original length, and all of the traumatized muscle was excised. Great care was taken not to open any new tissue planes and subject them to contamination. The wound was irrigated with 20 to 30 cc. of physiologic solution of sodium chloride and filled with one of the chemotherapeutic agents. In another group of animals debridement and irrigation were carried out, but no chemotherapeutic agent was applied to the wound. In still another group debridement and irrigation were not performed, but the chemotherapeutic agents were applied. Animals which received only initial wounding and contamination were used for controls. The amount of drug applied in each instance was 100 mg. except for sodium sulfathiazole, of which 150 mg. was necessary to fill the wound. The results of this experiment are recorded in table 1.

Experiment 2.—An incision 2 cm. long was carried through the skin and the subcutaneous tissue, and the underlying muscle was exposed. A block of muscle measuring on an average 1.5 by 1.5 by 0.5 cm. and having an average weight of 400 mg. was excised. In making this wound an effort was made to produce considerable trauma. Into each wound a small piece of sterile cotton was placed,

TABLE 3.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Septicum*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)
Controls	37	28	9	24
Sulfanilamide	15	1	14	93
Sulfadiazine	15	5	10	67
Sodium sulfadiazine	17	2	15	88
Sulfathiazole	15	0	15	100
Sodium sulfathiazole	15	1	14	93
Zinc peroxide	15	8	7	47

TABLE 4.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Novyi*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)
Controls	27	26	1	3.7
Sulfanilamide	10	10	0	0.0
Sulfadiazine	10	10	0	0.0
Sodium sulfadiazine	20	19	1	5.0
Sulfathiazole	10	10	0	0.0
Sodium sulfathiazole	20	16	4	20.0
Zinc peroxide	19	14	5	26.0

TABLE 5.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Sordellii*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)	Average Hours of Life
Controls	5	5	0	0	26
Sulfanilamide	5	5	0	0	34
Sulfadiazine	5	4	1	25	40
Sodium sulfadiazine	5	5	0	0	63
Sulfathiazole	5	4	1	25	61
Sodium sulfathiazole	5	5	0	0	81
Zinc peroxide	5	5	0	0	35

underneath which 0.5 cc. of an eighteen hour culture of Cl. septicum, Cl. novyi or Cl. sordellü was flooded. A dressing was applied.

Two hours after contamination the dressing and the saturated cotton were removed from one group of animals and a chemotherapeutic agent was placed in the wound. Neither irrigation nor debridement was carried out. The amounts of drugs used varied slightly since the object was to fill each wound and to bring the agent into contact with all parts. On an average 250 mg. of sulfadiazine or 500 mg. of the other agents was placed in each wound. The other group of animals received no treatment and was used as a control. The results of this experiment are recorded in tables 3, 4 and 5.

Experiment 3.—The operative technic and the method of contamination in this experiment were the same as for experiment 2. The manner of treatment differed in that one and one-half hours after contamination debridement of the wound followed by irrigation with physiologic solution of sodium chloride was carried out. Next 100 to 200 mg. of each chemotherapeutic agent was used, except for gramicidin, 0.5 cc. of which was placed into the wound on cotton. Three groups

TABLE 6.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Welchii*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)
Controls	5	3	2	40
Saline irrigation	5	4	1	20
Alcohol	5	4	1	20
Sulfanilamide	4	1	3	75
Zinc peroxide	5	2	3	60
Gramicidin	5	1	4	80

TABLE 7.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Septicum*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)
Controls	5	5	0	0
Saline irrigation	5	5	0	0
Alcohol	5	3	2	40
Sulfanilamide	5	3	2	40
Zinc peroxide	5	4	1	20
Gramicidin	5	3	2	40

TABLE 8.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Novyi*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)
Controls	3	3	0	0
Saline irrigation	3	3	0	0
Alcohol	3	2	1	33
Sulfanilamide	3	2	1	33
Zinc peroxide	3	2	1	33
Gramicidin	3	3	0	0

of animals served as controls. One group received no treatment; another received debridement and irrigation only, and the third received 0.5 cc. of 95 per cent alcohol. The last-named group served as a control for the gramicidin-treated animals inasmuch as this agent was administered in the form of an alcoholic extract. The results of this experiment are recorded in tables 6, 7 and 8.

Experiment 4.—The operative technic in this experiment was somewhat similar to that used in experiment 2. The same type of incision was used, and the same-

sized block of muscle was exposed. However, instead of the muscle being excised, it was thoroughly crushed with a hemostat. A small piece of cotton was inserted into the wound, and 0.5 cc. of a twenty-four hour culture of Cl. sordellii was flooded into the wound. At the end of two hours the traumatized muscle was excised; the wound was irrigated with physiologic solution of sodium chloride, and the chemotherapeutic agents in amounts used in experiment 2 were applied. One group of animals received debridement and irrigation only, and a third group received no treatment and was used as a control. The results of these experiments are recorded in table 9.

RESULTS OF EXPERIMENTS

The results of experiments 1, 2, 3 and 4 are presented in tables 1 to 10. To determine the significance of the difference between the various survival rates which appear in these tables the statistical method has been used. The value of such an analysis in estimating the significance of experimental data is self evident.

TABLE 9.—*Results of Local Chemotherapy in Experimental Wounds Contaminated with Cl. Sordellii*

	Total	Deaths	Recoveries	Survival Rate (Per Cent)	Average Hours of Life
Controls	3	3	0	0	35
Debridement and irrigation only	3	3	0	0	34
Sulfadiazine	3	3	0	0	50
Sodium sulfadiazine	3	3	0	0	68
Sulfathiazole	3	3	0	0	75
Sodium sulfathiazole	3	3	0	0	84
Zinc peroxide	3	3	0	0	40

Study of table 1, in which the results obtained with Cl. welchii are recorded, reveals that sulfadiazine, sulfathiazole and their sodium salts (used with or without debridement and irrigation) and sulfanilamide (used with debridement and irrigation) each increases the survival rate when compared with that for the control animals to a figure which has statistical significance. The survival rate for the animals treated with sulfanilamide without debridement and irrigation and with zinc peroxide plus debridement and irrigation when compared with the survival rate for the controls is not of statistical significance. It will be noted in table 2 that chemotherapy combined with debridement and irrigation is superior to chemotherapy used alone. This observation is in conformity with well accepted principles of surgery. On the other hand, we are at a loss for an explanation of the fact that there is no difference (the difference between 30 and 20 per cent in this instance is not of statistical significance) between the survival rates for the controls and for the animals treated by debridement and irrigation.

From a study of table 3, in which the results with Cl. septicum are recorded, we find that the difference between the survival rates for animals treated with each of the sulfonamide compounds used (sulfanilamide, sulfadiazine, sulfathiazole, sodium sulfadiazine and sodium sulfathiazole) considered individually and the controls is of statistical significance. The difference between the survival rate for the zinc peroxide–treated group of animals and the control group is not of statistical significance. The conclusion to be drawn here is that in the prevention of gas gangrene in Cl. septicum–contaminated wounds the aforementioned sulfonamide compounds are of definite value while zinc peroxide is of uncertain value.

Table 4 records the results of experiments with Cl. novyi and reveals that except for sodium sulfathiazole the sulfonamide compounds used were of little or no value in preventing death from gas gangrene due to

TABLE 10.—*Average Survival Time After Local Chemotherapy in Experimental Wounds Contaminated with Cl. Sordellii*

	Average Survival Time (Hr.)
Control	20.5
Debridement and irrigation only	34.0
Sulfanilamide	33.0
Zinc peroxide	39.6
Sulfadiazine	48.0
Sulfathiazole	67.0
Sodium sulfadiazine	68.0
Sodium sulfathiazole	82.0

this organism. The difference between the survival rate for the sodium sulfathiazole–treated animals and that for the controls is not of statistical significance. However, the survival rate obtained among the zinc peroxide–treated animals, viz. 26 per cent, is significant. From this we conclude that zinc peroxide has definite value in preventing the development of gas gangrene in Cl. novyi–contaminated wounds.

Tables 5 and 9 show the results of the experiments with Cl. sordellii. It is obvious from these tables that chemotherapy used after a two hour interval is of no value in preventing death from experimental gas gangrene due to this organism. When one considers these two tables together and calculates in hours the average time of survival for the animals, the results shown in table 10 are obtained.

It is apparent from table 10 that by using sulfathiazole, sulfadiazine or their sodium salts the average duration of life of the animals can be doubled when compared with that of the controls and that while these chemotherapeutic agents do not prevent gas gangrene in Cl. sordellii–contaminated experimental wounds they do retard its development.

Tables 6, 7 and 8 record the results of additional experiments with Cl. welchii, Cl. septicum and Cl. novyi. The only information added as the result of these experiments is that the use of an alcoholic extract of gramicidin is of value in preventing gas gangrene in Cl. welchii–contaminated wounds. This agent is of little or no value against the two other organisms. These are interesting observations, but until further experiments with gramicidin are performed, their importance should not be overemphasized.

The lesions produced in guinea pigs by each species of Clostridium under the conditions of these experiments presented certain characteristics which are worthy of note.

Cl. Welchii.—Animals infected with Cl. welchii showed in the first twenty-four to forty-eight hours following contamination extensive edema, discoloration and crepitation involving the thigh and spreading along the subcutaneous tissues of the abdomen and the thorax. Surprisingly, in some instances infections as extensive as this subsided spontaneously. Occasionally animals died before the disease progressed to such a point. Those living longer than forty-eight to seventy-two hours almost always showed necrosis around the wound and in the thigh and occasionally on the abdominal wall. A number of these lesions healed, and the animals ultimately recovered. Among the Cl. welchii–infected animals that died there was a rather typical picture. Around the wound (and here the extent seemed to depend on how long the animal had survived the infection), the muscle was pale and necrotic. Beyond this area there was congestion of the muscles, gas and hemorrhagic exudate in the tissue planes. The spread of the exudate was most rapid along the subcutaneous tissue planes. The exudate was usually serosanguineous but occasionally was slightly gelatinous. This fluid consistently yielded Cl. welchii on culture, and frequently the organism could be grown from the blood stream. The mortality rate in all experiments for all untreated control animals of the Cl. welchii group was 73 per cent, and the average duration of life for those controls that died was fifty hours from the time of contamination.

Many of the features of the Cl. welchii infection were observed in gas gangrene due to Cl. septicum, Cl. novyi and Cl. sordellii, particularly the mode of spread and the presence of the organisms in exudate and heart's blood. There were, however, certain features which made it possible to distinguish these lesions from one another.

Cl. Septicum.—The mortality rate among all the Cl. septicum–contaminated controls was 80 per cent, and the average duration of life was nineteen hours. Animals with Cl. septicum infections died before showing as extensive clinical disease as did those infected with the other species; the process once initiated was rapid. At autopsy the chief distinguishing characteristic of Cl. septicum infection was the brilliant

red color of the muscle involved. The exudate and other features presented a picture not unlike that of infections with Cl. welchii save for the fact that little or no necrosis was evident.

Cl. Novyi.—The animals infected with Cl. novyi were characterized by the extensive edema of the thigh and the abdominal wall. In many instances this extended to the level of the axillas. At autopsy there was usually a limited zone of necrosis at the site of the original muscle wound and hemorrhage, exudate and gas in the tissues immediately surrounding. Muscle was usually congested but not so brilliantly as in Cl. septicum infections. The exudate in the subcutaneous tissues of the abdominal wall and the thorax was thick and gelatinous and almost colorless. The mortality rate among all of the untreated controls was 97 per cent, and the average duration of life was seventy hours.

Cl. Sordellii.—Infections due to Cl. sordellii were not unlike those caused by Cl. novyi save for the fact that the colorless gelatinous edema was thicker and more extensive. None of the control animals in this group survived, and the average duration of life of the control animals after contamination was twenty-nine hours.

COMMENT

Infection in the experiments carried out by many observers was produced by subcutaneous, intramuscular or intraperitoneal needle injection of the organisms. These methods, while they afford a satisfactory and consistent mode of producing gas gangrene in laboratory animals, differ so greatly from the manner in which contamination or infection takes place in traumatic wounds in human beings that the results cannot be accurately compared with the conditions which actually prevail in fresh traumatic wounds in human beings.

In studying this problem it has seemed to us that nothing less than a true to life method of effecting trauma, contamination and prophylaxis or treatment in experimental animals should be employed to draw comparisons with gas gangrene in human beings. A wound reproducing accurately all true to life factors and eliminating all artificial elements cannot be produced in experimental animals under laboratory conditions. Our purpose has been, therefore, to simulate as closely as possible contaminated traumatic wounds in human beings, at the same time endeavoring to keep such wounds simple in order to avoid the introduction of extraneous factors.

For this reason the use of such foreign bodies as metal or soil embedded in the tissues was decided against. We did, however, in some experiments place a small piece of cotton superficially in the wound in order to retain the inoculum and prevent its spilling from the wound.

This simulated foreign bodies such as clothing. Bone trauma (i. e. experimental compound fracture) was not studied because of its great variation.

Once the wounds were produced and contaminated, the question was raised whether to close these wounds with suture material or to leave them open. It was decided to leave them open on the basis of greater simplicity and the closer similarity to human lesions. While we feel that a muscle wound produced, contaminated and left without closing with suture material constitutes a more nearly true to life situation than does any type of wound heretofore suggested, we in no sense believe that our method is the final answer to the problem of producing the experimental lesion. The fact that with Cl. welchii and Cl. septicum 27 and 20 per cent respectively of the untreated control animals survived is sufficient to suggest that improvement in our method needs to be sought. It is entirely possible that some of the wounds failed to offer adequate anaerobic conditions and that hence a certain percentage of control animals survived. In this connection it is interesting to note the observation of Reed and Orr that if the wounds were left open or if they subsequently opened as a result of incomplete or faulty closure, infections failed to develop in a fair number of animals, or transient infections developed from which the animals recovered without treatment. Using a wound closed with sutures, both Reed and Orr and Hawking were able to obtain a higher mortality rate among their control animals than we were, using a contaminated but unsutured wound.

We believe that in order to obtain true to life conditions of prophylaxis an interval must lapse between contamination of the experimentally produced wound and the introduction of the chemotherapeutic agent, a factor which some workers have not taken into consideration. Two hours was decided on as a desirable interval. Possible objection might be raised to the shortness of this period when compared with the time which lapses between injury and treatment of human patients, particularly in wartime. It must be pointed out that two hours seems to us a fair interval on the basis of the facts that in small untreated laboratory animals gas gangrene is a rapidly progressive disease and that the interval between contamination and death is but a fraction of the time which usually intervenes in human patients. There should be further studies in which varying periods are allowed to intervene between contamination and treatment.

Local application of the chemotherapeutic agent was the only method of treatment used. There is already at hand sufficient data to indicate that in experimental gas gangrene local application is more efficacious than oral or parenteral administration of the sulfonamide compounds. For zinc peroxide and gramicidin the local route is the only one feasible. The quantity of drug used was based on the amount necessary to fill

the wound and to make adequate contact with all parts of it rather than on the body weight of the animal. When the amount of sulfonamide compound placed in each wound is calculated on the basis of the body weight of the animal and comparison is made with the customary doses for human beings, it becomes apparent that a generous amount was used in each instance.

Only pure cultures of pathogenic Clostridia were used to produce gas gangrene in our experiments. It must be emphasized that in this respect experimental gas gangrene as produced in this study as well as in that of many other observers differs from clinical gas gangrene in human beings. Frequently in clinical cases other organisms, both aerobic and anaerobic, are isolated in addition to one or more of the pathogenic Clostridia, and in such instances the possibility of synergism should be kept in mind. Studies using mixtures of organisms as well as mixtures of chemotherapeutic agents are clearly indicated.

As has been pointed out previously, lack of uniformity in methods renders accurate correlation between observations of the various authors almost impossible. There are, however, several outstanding discrepancies as well as certain points of agreement which seem worth commenting on and comparing with our own results.

In regard to Cl. welchii infections treated with sulfanilamide, Hawking reports 72 per cent survivals, Reed and Orr, 40 per cent, Bonnin and Fenner, 80 per cent and Bliss, Long and Smith, complete failure. All of these observers administered drug and organisms simultaneously. In experiments in which an interval was allowed to lapse between contamination and therapy, we find our own result of 100 per cent, that of Caldwell of 21 per cent and that of Reed and Orr of 0 per cent. Sulfadiazine as used against Cl. welchii by Reed and Orr yielded 80 per cent survivals, and as used by us, 70 per cent survivals, compared with 43 per cent obtained by Hawking and 26 per cent obtained by Bliss, Long and Smith. With sulfathiazole Reed and Orr saved 97 per cent of their animals; we were able to save 75 per cent; Hawking saved 76 per cent, and Bliss, Long and Smith, 13 per cent.

One of the most outstanding discrepancies is that concerning the use of zinc peroxide against Cl. welchii. This agent in the experiments of Johnson and Meleney was found to be 94 per cent effective, whereas Bliss, Long and Smith using essentially the same technic found that only 1.7 per cent of their animals were saved. This is difficult to understand even when the fact is taken into consideration that guinea pigs were the experimental animals for one group of observers and mice for the other. When Reed and Orr allowed three hours to lapse between contamination and treatment, 60 per cent of their zinc peroxide–treated animals survived. This is comparable to our own result of 60 per cent under similar conditions.

With Cl. septicum as the organism and sulfanilamide as the drug, Bliss, Long and Smith, Bonnin and Fenner and Hawking encountered complete failure, while Reed and Orr had 25 per cent survivals as compared with our own survival rate of 100 per cent. Using sulfadiazine, Reed and Orr obtained 100 per cent recoveries and Bliss, Long and Smith, 98 per cent, as against our own of 67 per cent. With sulfathiazole, Reed and Orr reported 87 per cent survivals; Hawking, 75 per cent, and Bliss, Long and Smith, 58 per cent, while the results reported by us were 100 per cent survivals, even when a two hour period lapsed between contamination and treatment. It is particularly interesting to note that when Reed and Orr allowed a three hour and a six hour interval to intervene they also obtained 100 per cent survivals. With zinc peroxide against Cl. septicum there is similarity in the results of several observers. In those experiments in which the organisms and the chemotherapeutic agent were administered simultaneously, Reed and Orr obtained 50 per cent survivals, and Bliss, Long and Smith, 62 per cent. On the other hand, when Reed and Orr allowed an interval of three or six hours to intervene, 30 per cent of their animals survived. In our series 47 per cent survived.

Concerning the results with Cl. novyi there is more uniform agreement; yet even here discrepancies continue to appear. Using sulfanilamide against this organism Reed and Orr and Hawking had 24 and 28 per cent survivals respectively, whereas the experiments of Bliss, Long and Smith, Bonnin and Fenner and us showed no recoveries. Using sulfadiazine Reed and Orr obtained 40 per cent recoveries when the drug and the organisms were given simultaneously and 100 per cent when an interval was allowed. With this same drug and organism Bliss, Long and Smith obtained 4 per cent survivals, and we had none. Sulfathiazole gave even better results against Cl. novyi as used by Reed and Orr, who obtained 85 per cent survivals when the drug was administered at the same time as the organisms. When two and three hours intervened, the results were even better, viz. 100 per cent. Hawking obtained 33 per cent survivals; Bliss, Long and Smith, 6 per cent, and we again had none. Using zinc peroxide against Cl. novyi and administering the drug and the organisms simultaneously, Reed and Orr had 100 per cent survivals, and Bliss, Long and Smith, 98 per cent. When three hours lapsed between contamination and therapy, Reed and Orr encountered complete failure, but in experiments in which six hours lapsed they reported 40 per cent recoveries, giving a mean of 20 per cent, which is comparable to our own survival rate of 26 per cent.

In no sense are these comparisons to be considered as a complete report on all of the work done along these lines, nor are they even to be thought of as representing all of the observations made by any one observer. Certain findings, however, have been briefly reviewed from

which comparisons can be made. The recording of them serves to emphasize the need for a uniform method of study for this problem.

Because a clearcut and universally accepted decision has not been reached as the result of laboratory investigation, the question is raised whether or not we should give up all animal experimentation and await the results of clinical studies. While it is perfectly obvious that the final answer as to the value of chemotherapy in the prophylaxis and the treatment of gas gangrene can come only after extensive clinical study, it is equally apparent that there is much to be learned from further animal experimentation. From time to time in this report we have suggested possible avenues for additional study which should be used not only with the chemotherapeutic agents already available but with additional ones as they are discovered. Further studies, however, should be coordinated so that comparisons can be made both with other laboratory experiments and with clinical observations. Much reduplication of effort would be eliminated if those interested in experimental as well as clinical gas gangrene would agree on the most suitable approach to the experimental problem.

CONCLUSIONS

While there are considerable data on the use of the newer chemotherapeutic agents in the treatment of experimental gas gangrene, there is lack of agreement among the various observers as to the value of these agents. Correlation of the results reported in the literature is made difficult because of a lack of uniformity in methods.

A method is presented for the production in experimental animals of wounds contaminated with the species of clostridia associated with clinical gas gangrene. These wounds simulate acute traumatic wounds in human beings and if untreated lead in a large proportion of the animals to the development of gas gangrene and death.

When used in such experimental wounds within two hours after production and contamination, sulfanilamide, sulfadiazine, sulfathiazole and the sodium salts of the latter two are effective in the prevention of death from gas gangrene in animals whose wounds are contaminated with either Cl. welchii or Cl. septicum. The effectiveness of zinc peroxide in such wounds has not been convincingly demonstrated by our experiments.

Under the same conditions zinc peroxide is effective in producing a slight but statistically significant reduction in mortality from gas gangrene in animals with Cl. novyi–contaminated wounds. Sodium sulfathiazole approaches zinc peroxide in effectiveness, but the reduction in mortality is not statistically significant. Complete failure was encountered with the other sulfonamide compounds in Cl. novyi–contaminated wounds.

None of the chemotherapeutic agents studied were effective in preventing death from gas gangrene in animals whose experimental traumatic wounds were contaminated with Cl. sordellii. Yet sulfadiazine, sulfathiazole and their sodium salts were effective in producing significant delay in death from gas gangrene.

In animals with Cl. welchii–contaminated wounds, debridement and irrigation of the wounds in addition to chemotherapy are of significantly greater value than the use of chemotherapy alone. However, debridement and irrigation without chemotherapy gave results not significantly different from those obtained in the untreated controls.

In general, sulfadiazine, sulfathiazole and their sodium salts are more effective in preventing experimental gas gangrene than is sulfanilamide. Except in the Cl. novyi–contaminated wounds there is no significant difference between sulfathiazole and its sodium salt; however, sodium sulfadiazine appears to be superior to sulfadiazine.

A standard type of wound and uniform method of approach are needed so that further experimentation can go forward on a basis suitable for making comparisons. Since the results in this problem have a direct clinical application, experiments should as closely as possible mirror clinical conditions.

We have attempted to point out the complexity of the problem and have emphasized the fact that the multiplicity of the factors involved may considerably alter the results obtained. There should be a consensus among investigators in this field in order that the experimental methods may be standardized with regard to the lesion produced, the contaminating organisms to be used, the dosage and the method of administration of the treatment to be instituted, the experimental animals to be employed and the criteria to be used in determining the results.

The discrepancies in the results so far obtained in experimental gas gangrene clearly indicate that further studies must be carried out before the newer chemotherapeutic agents can be properly evaluated.

180 Fort Washington Avenue.

INTERPELVIABDOMINAL AMPUTATION

REPORT OF THREE CASES

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On April 19, 1935, I successfully performed a one stage interpelviabdominal amputation for an osteochondroma of the pelvis on a man 24 years of age. At the time of writing he is still alive and active. While I had performed interscapulothoracic amputation a number of times and had disarticulated the hip several times in the past few years, I had never had the opportunity before to perform this extremely mutilating operation, and I was somewhat at a loss as to the correct procedure. I had read about the operation as reported by Keen,[1] Pringle[2] and Judin,[3] but otherwise I was in the same stage of uncertainty as the French surgeon, Leriche,[4] who recently stated that when the occasion arose to perform this major operation, he was unfamiliar with the operation, had never done it and had never seen it done. He might also have added that it was probably true that none of his conferees were in a position to aid him.

REPORT OF CASES

CASE 1.— F. S., a man aged 24, was admitted to the Barnard Free Skin and Cancer Hospital on April 8, 1935, with a history of having noticed a growth on the right hip about eight months before for which he consulted a physician who told him to return for observation. His physician dying shortly after, he neglected to see another. The tumor continued to grow and caused some pain, especially at night. Examination at this time revealed a large tumor on the back involving the wing of the right ilium; this was extremely painful. The Wassermann test gave a negative result, although there was a history of a chancre four years before for which the patient received eight injections. There was also a history of gonorrhea eight years previously. Otherwise he had been in good health. There was no familial history of cancer. Roentgen examination at this time showed a tumor mass involving the wing of the ilium; this was pronounced an osteogenic sarcoma.

From the surgical service of Dr. W. E. Leighton, Barnard Free Skin and Cancer Hospital, and St. Louis University School of Medicine.

1. Keen, W. W., and da Costa, J. C.: Internat. Clin. **4**:127, 1904.
2. Pringle, J. H.: Lancet **1**:530, 1909; Brit. J. Surg. **4**:283, 1916.
3. Judin, S. S.: Surg., Gynec. & Obst. **43**:668, 1926.
4. Leriche, R., and Stuz, E.: Presse méd. **44**:65, 1936.

Fig. 1 (case 1).—Roentgenogram showing large tumor involving the wing of the right ilium.

Fig. 2 (case 1).—Photograph of patient taken after interpelviabdominal amputation.

On April 19, with the patient under spinal anesthesia, an interpelviabdominal amputation was performed. The incision used was that described by Keen, which is somewhat similar to that of Savariaud.[5] Both incisions employ a long lateral musculocutaneous flap, preserving the adductor group of muscles with their attachments to the pubis and the ischium and the femoral vessel. The rami of the ischium and the pubis were divided with the Gigli saw, the attachment of the adductor muscles being preserved. The posterior incision passed around the tumor mass from the anterior superior spine to the tuberosity of the ischium, and the ilium was disarticulated. By dividing the gluteus maximus muscle and the piriformis muscle, the leg was readily removed. All large vessels were caught and ligated before severance. The lateral flap was turned outward and backward, and the muscles and the skin were approximated. A rubber dam drain was placed in the lower angle of the wound. Considerable shock followed the operation, but a blood transfusion relieved the immediate danger. There was free drainage from the wound for several days. The patient was out of bed and up in a wheel chair in about three weeks. He was around on crutches within two months. He was discharged with his wound healed soon after. The pathologic report was osteochondroma.

He has been seen repeatedly since and is in good health at the time of writing, six years after the operation.

CASE 2.—Mrs. B. F., a 44 year old woman, was admitted to St. Luke's Hospital on Oct. 22, 1939, because of swelling and pain in the right groin during the past year. The pain radiated from the right sacrosciatic region and the right hip downward.

Pelvic examination at this time revealed the uterus and the cervix incorporated in a fixed semisolid mass which was not tender. The adnexa were not palpable. The mass gave me the impression of a pelvic carcinoma.

Roentgen examination at this time showed a bony tumor arising from the brim of the pelvis and projecting into the cavity of the pelvis. A chest plate did not reveal any pulmonary involvement. A diagnosis of osteosarcoma was made. Biopsy performed on October 23 revealed chondrosarcoma.

The serious nature of the disease was explained to the patient, and she consented to a radical amputation. On November 8, an interpelviabdominal amputation was performed according to the technic of Judin, which consists in making a large posterior lateral flap, preserving the gluteus maximus muscle which gives a firm muscular support for the abdomen.

In the week between biopsy and operation a considerable infiltration of the tissues at the site of incision occurred; this illustrates the danger of delaying operation following biopsy.

There was considerable shock; this had been anticipated by a transfusion of 500 cc. of blood on two previous alternate days. A postoperative transfusion of 500 cc. of blood improved her condition. The blood pressure the following day was 100 systolic and 80 diastolic. The pulse was of fair quality. The wound drained freely, and the stitches were removed on the twelfth day. About one month later there was a suspicious-looking area in the upper part of the wound which on biopsy was diagnosed as chondrosarcoma. The general condition grad-

5. Savariaud: Rev. de chir. **26**:345, 1902.

ually grew worse, and the patient died on Jan. 7, 1940, just two months after the operation. At autopsy the growth was shown to have spread from the pelvis along the vessels to the lungs, which were involved in the metastasis.

Fig. 3 (case 2).—Roentgenogram showing a bony tumor arising from the brim of the pelvis and projecting into the cavity.

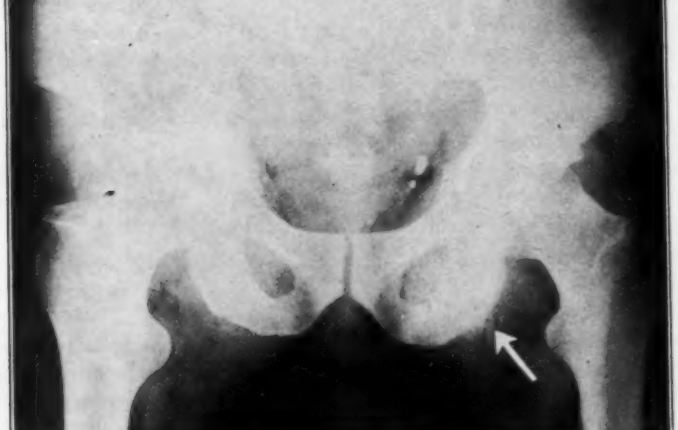

Fig. 4 (case 3).—Roentgenogram showing a tumor of the left ischium involving the ramus to the margin of the acetabulum.

CASE 3.—J. R., a 47 year old man, entered St. Mary's Hospital on May 12, 1941. He had received a severe jolt while riding horseback ten days previously. He struck the cantle of the saddle so hard that he thought he had broken his

leg. He went home and consulted his family physician. Examination at that time did not show a palpable tumor but did reveal some tenderness in the region of the ischium. Roentgen examination revealed a tumor of the left ischium involving the ramus to the margin of the acetabulum.

A diagnosis of osteogenic sarcoma was made. Palliative treatment by irradiation not being successful in these cases, radical amputation was advised. This the patient accepted, and on May 14 an interpelviabdominal amputation was performed with the patient under both spinal and general anesthesia, the latter induced with ether. The technic employed was that described by Judin, the details of which I shall presently describe. The pathologic report was osteosarcoma. There was little shock; however, 500 cc. of blood was given. The patient made a good recovery from the operation. There was free drainage. The stitches were removed on the twelfth day. The patient was out of bed and using crutches on June 2 and was discharged from the hospital on June 5. He was seen on December 9. He had gained in weight, was going about on crutches and driving his automobile.

COMMENT

The hindquarter amputation, known most commonly as the interilioabdominal amputation, has been given various names, such as hemipelvectomy, interinominoabdominal amputation, interpelviabdominal amputation and interiliosacropubic disarticulation. While interinominoabdominal amputation would seem to be the correct term, I have used the title interpelviabdominal amputation, adopted by the Committee on Surgical Nomenclature of the Western Surgical Association.

Since the first interpelviabdominal operation by Billroth in 1891, there have been recorded in the literature 108 operations. In the first 21 cases reported by Ransohoff,[6] there was a mortality rate of 75 per cent, most of the deaths occurring on the operating table or shortly after operation. In a report by Pringle of a comparable number of cases, a total mortality rate in 42 cases was 58.1 per cent; and in the tabulation by Gordon-Taylor[7] of 79 cases in 1934, the mortality rate remained over 50 per cent.

Since 1935 I have successfully performed the interpelviabdominal amputation 3 times. There have been reports of 19 similar operations, 17 of which I have reviewed. Two reports from the Russian literature were not obtained. There were 3 deaths in the series. For the total verified 20 cases, the mortality rate was 15 per cent, a striking difference in comparison with any of the previous reports.

The indications for this rarely used procedure have been primary tumors, either benign or malignant, of the femur, the thigh or the pelvis, metastatic growths of the pelvis and tuberculous or nontuberculous osteomyelitis of the hip, the pelvis or both. It is an operation with a high initial mortality rate; shock and prolonged suppuration are the chief

6. Ransohoff, J.: Ann. Surg. **50**:925, 1909.
7. Gordon-Taylor, G., and Wiles, P.: Brit. J. Surg. **22**:671, 1934.

causes of early death. For this reason it should be undertaken only after serious consideration of the physical condition of the patient and the measures to combat shock. As one author stated, "it is the most collossal multilation that can be inflicted on the human body."

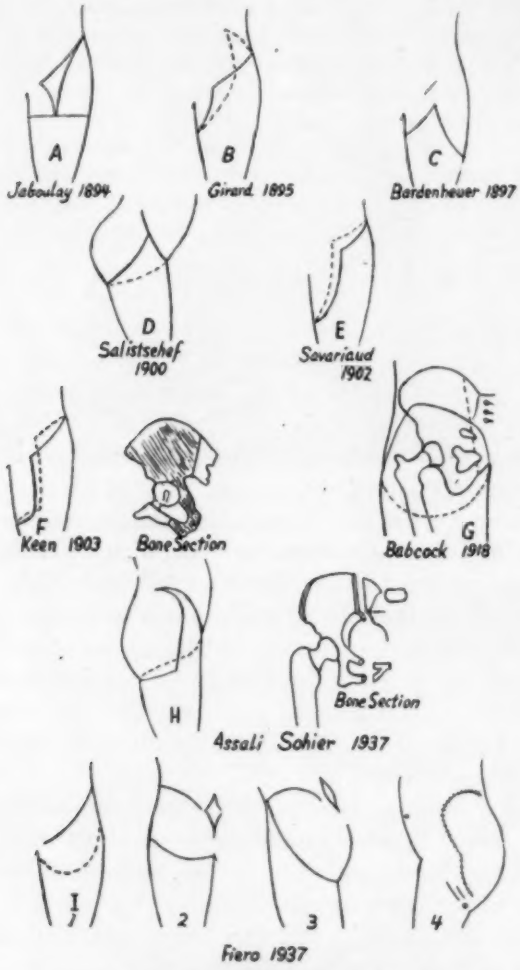

Fig. 5.—Chart showing incisions used by various authors for interpelvi-abdominal amputation.

In a few instances an amputation at the hip or the thigh has preceded division of the pelvic bone, but in the large majority of cases a one stage operation has been employed.

DESCRIPTION OF THE OPERATION

The operation, described by Salistschef and somewhat modified since, consists principally of the formation of an external or gluteal flap, a satisfactory operation in many cases. It may be divided into two stages.

First Stage.—With the patient on his back, the incision is begun at the posterior superior spine of the ilium and is extended by following along the crest and the ilioinguinal ligament nearly to the spine of the

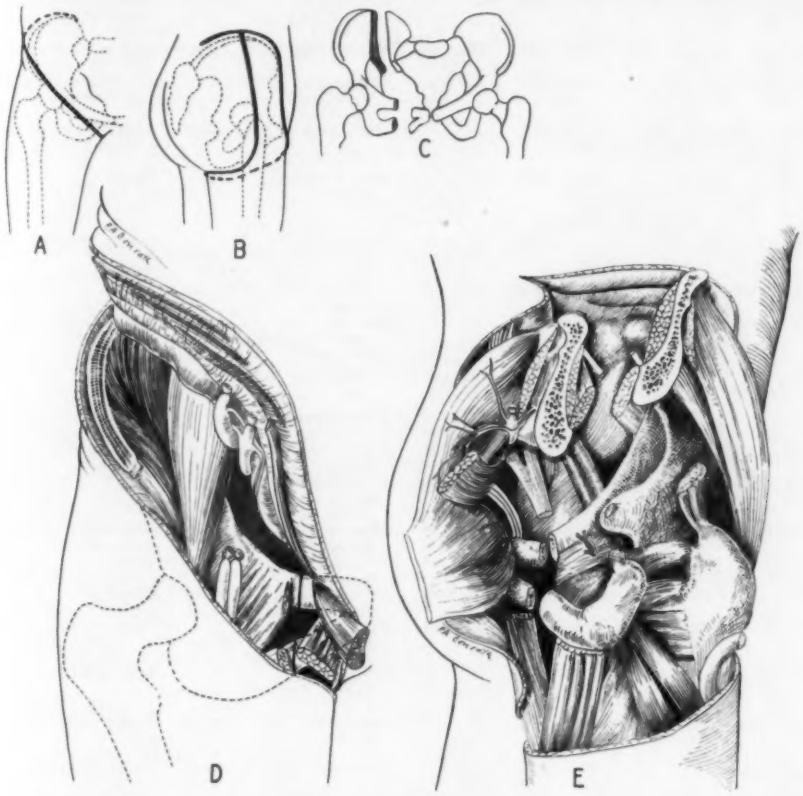

Fig. 6.—*A, B, C* and *D*, drawings showing incision for reflecting the abdominal wall with the peritoneum, ligature of the external iliac artery and vein and the line of division of the pubis; *E*, lateral incision with reflection of the gluteus maximus muscle to expose the sciatic plexus and the gluteal artery and division of the ilium (redrawn after the method of J. Assali and H. Sohier [J. de chir. **50**:310, 1937]).

pubis. It is then curved downward on the inner part of the thigh to the gluteal groove. The abdominal muscles are divided at their origin from the crest of the ilium, and the ilioinguinal ligament is divided at each end. The iliac vessels are then exposed. The artery is ligated

TABLE 1.—*Cases of Interpelviabdominal Amputation Reported in the Literature*

Author	Year	Sex of Patient	Age of Patient, Yr.	Disease	Anesthesia	Result
Billroth, cited by Savariaud: Rev. de chir. **26**: 350, 1902	1891	..	..	.....	.....	Died in few hours
Jaboulay: Lyon méd. **75**: 507, 1894	1894	..	..	Sarcoma of femur	General	Died following day
Jaboulay, cited by Gayet: Province méd. **9**: 34 and 397, 1895	1895	M	66	Sarcoma of pelvis	.....	Died 36 hours later
Cacciopoli: Riforma med. **10** (pt. 2): 819-831, 1894	1894	M	17	Sarcoma of femur	.....	Died 3 hours later
Girard: Rev. de chir. **15**: 952, 1895	1894	F	17	Sarcoma of femur and pelvis	General	Alive after 7 mo.; metastasis
Girard: Rev. de chir. **18**: 1141, 1898	1895	M	15	Tuberculosis	.....	Died in 5 minutes
Girard: Rev. de chir. **18**: 1141, 1898	1897	M	52	Sarcoma of femur and pelvis	.....	Alive after 6 mo.; metastasis
Bardenheuer: Ber. ü. d. deutsch. Gesellsch. f. Chir. **26**: 132, 1897	1897	F	46	Tuberculosis	.....	Lived 10 mo. or more
Kocher: Text-Book of Operative Surgery, translated by H. J. Stiles, London, A. & C. Black, 1903	1898	M	..	Sarcoma of pelvis	.....	Death
Faure: Rev. de gynec. et chir. abdom. **3**: 713, 1899; cited by Savariaud	1899	F	16	Sarcoma of pelvis	.....	Died 1 day later
Salistschef: Arch. f. klin. Chir. **60**: 57, 1900	1899	M	38	Sarcoma of femur	General	Lived
Freeman: Ann. Surg. **33**: 318, 1901	1899	F	38	Sarcoma of femur	.....	Lived 16 mo. or more
Kadjan: Lystopis russ. chir. 1900, vol. 4; abstracted, Jahresb. f. Chir. **2**: 1104, 1902	1900	M	25	Sarcoma of femur	General	Died 2 days later
Nanu: Rev. de chir. **26**: 365, 1902	1900	M	50	Myxosarcoma of pelvis	General	Died 20 days later from gangrene
Pringle: Lancet **1**: 530, 1909	1900	F	10	Tuberculosis of hip	.....	Lived 14 years
Pringle: Lancet **1**: 530, 1909	1906	M	Adult	Tuberculosis of hip and pelvis	.....	Died after 14 hr.
Pringle: Lancet **1**: 530, 1909	1908	M	18	Sarcoma of femur	Spinal (2/12/08)	Alive after 5 mo.; metastasis
Pringle: Brit. J. Surg. **4**: 283, 1916	1015	M	34	Sarcoma of femur	.....	Lived
Pringle: Brit. J. Surg. **4**: 283, 1916	1915	F	46	Sarcoma of femur	Spinal (8/3/15)	Lived
Gallet: J. de chir. et ann. Soc. belge de chir. **1**: 569, 1901	1901	M	25	Tuberculosis	.....	Died 6 hr. later
Gallet: J. de chir. et ann. Soc. belge de chir. **1**: 569, 1901	1901	F	39	Sarcoma of femur	.....	Died same day
Savariaud: Rev. de chir. **26**: 345, 1902 (quotes Girard and previous authors)	1901	F	7	Sarcoma of pelvis	.....	Died 2 hr. later
Mikhailoff: Khirurgiya **11**: 471, 1902; cited by Judin [3]	1902	..	..	Tuberculosis	General	Died ¾ hr. later
Morestin: Bull. et mém. Soc. anat. de Paris **4**: 795, 1902	1902	F	?	Sarcoma of pelvis	.....	Died 9 hr. later
Morestin: Bull. et mém. Soc. de chir. Paris **34**: 1060, 1908	1905	M	?	Tuberculosis	.....	Lived 3 yr. or more
Morestin: Bull. et mém. Soc. anat. de Paris **11**: 288, 1909	1909	M	35	Tuberculosis	.....	Died 14 hr. later
DeRuyter, cited by Meyer, H.: Ein Beitrag zur Exarticulatio inter- ilio-abdominalis, Inaug. Dissert., Leipzig, 1902	1902	M	45	Sarcoma of femur	.....	Died 1 hr. later
Ribera, cited by Simon: Siglo méd. **1**: 779, 1903	1902	?	8	Tuberculosis	.....	Died 8 days later from gangrene
Ribera, cited by Simon: Siglo méd. **1**: 779, 1903	1902	?	8	Tuberculosis	.....	Died soon after
Ribera, cited by Simon: Siglo méd. **1**: 779, 1903	1902	F	10	Tuberculosis	.....	Died 3 hr. later
Christel, cited by Driest: Deutsche Ztschr. f. Chir. **71**: 4, 1904	1903	F	2	Tuberculosis	.....	Lived

TABLE 1.—*Cases of Interpelviabdominal Amputation Reported in the Literature—Continued*

Author	Year	Sex of Patient	Age of Patient, Yr.	Disease	Anesthesia	Result
Keen and DaCosta [1]	1903	M	42	Sarcoma of pelvis	.....	Died 33 hr. later
Verneuil: J. de chir. et ann. Soc. belge de chir. **5**: 406, 1905	1905	..	..	Tuberculosis	.....	Died 2 hr. later
Lastaria: Riforma med. **23**: 457, 1907	1906	M	22	Chondrosarcoma	.....	Died on table
Orloff: Vestnik khir. **2**: 225, 1901; abstracted, Jahresb. ü. d. Fortschr. a. d. Geb. d. Chir. **7**: 1104, 1907	1907	M	47	Sarcoma of femur and pelvis	.....	Died 35 days later from sepsis
Bier: Deutsche med. Wchnschr. **35**: 45, 1909	1908	M	45	Sarcoma of pelvis	Spinal	Lived 2 mo.
Sinakevitch: Khirurgiya **27**: 60, 1910; cited by Judin [2]	1908	M	47	Sarcoma of femur and pelvis	.....	Died a few hours later
Krynsky: abstracted, Zentralbl. f. Chir. **37**: 1132, 1910	1908	..	..	Sarcoma of femur and pelvis	Spinal	Alive after 5 wk.; cachexia
Pagenstecher: Arch. f. klin. Chir. **90**: 160, 1909	1909	F	50	Sarcoma of pelvis	.....	Lived 3 mo. or more
Ransohoff: Ann. Surg. **50**: 925, 1909	1909	M	45	Sarcoma of pelvis	General	Died 4 wk. later from enterocolitis
Roux, cited by Plantard: Arch. prov. de chir. **18**: 657, 1909	1909	M	40	Sarcoma	.....	Lived 3 mo. or more
Axhausen: Arch. f. klin. Chir. **91**: 538, 1910	1910	F	45	Sarcoma	General	Died 9 hr. later
Krim: Khirurgiya **34**: 763, 1913; cited by Judin [2]	1913	F	27	Sarcoma of pelvis	General	Died 13 days later
Gaudier: Bull. et mém. Soc. de chir. de Paris **39**: 1570, 1913	1913	M	15	Nontuberculous osteomyelitis	.....	Lived
Babcock: Surg., Gynec. & Obst. **26**: 554, 1918	1914	M	28	Marjolin ulcer	.....	Lived 4 mo.
Babcock: Surg., Gynec. & Obst. **26**: 554, 1918	1915	F	56	Sarcoma of pelvis	.....	Lived 10 weeks
Babcock: Surg., Gynec. & Obst. **26**: 554, 1918	1916	M	52	Marjolin ulcer	.....	Died shortly after operation
Babcock: Textbook of Surgery, Philadelphia, W. B. Saunders Company, 1928						
Babcock: Textbook of Surgery, Philadelphia, W. B. Saunders Company, 1928						
Maffei: Proc. Soc. internat. de chir. orthop., 1933, p. 270	1915	F	5	Tuberculosis of hip	.....	Well 17 yr. later
Maffei: Proc. Soc. internat. de chir. orthop., 1933, p. 270	1915	M	8	Tuberculosis of hip	.....	Lived 1 mo.
Maffei: Proc. Soc. internat. de chir. orthop., 1933, p. 270	1915	..	3	Tuberculosis of hip	.....	Died 2 hr. later
Loeffler: Ztschr. f. orthop. Chir. **39**: 305, 1919	1918	M	11	Sarcoma of pelvis	.....	Lived 15 mo. or longer
Bergmann, cited by Judin [2]	1918	..	..	Nontuberculous osteomyelitis	.....	.....
Bergmann, cited by Judin [2]	1918	..	..	Nontuberculous osteomyelitis	.....	.....
Bergmann, cited by Judin [2]	1918	..	..	Nontuberculous osteomyelitis	.....	.....
Bergmann, cited by Judin [2]	1918	..	..	Nontuberculous osteomyelitis	.....	.....
Bergmann, cited by Judin [2]	1918	..	..	Nontuberculous osteomyelitis	.....	.....
Smirnov, cited by Judin [2]	1919	M	33	Tuberculosis	.....	Died on table
Toprover-Krimov: Ekaterinos lav. M. J. (no. 1) **2**: 44, 1925; cited by Judin [2]	1919	M	47	Sarcoma of femur	General	Alive after 2 mo.; metastasis to lung
Veinshall: Nov. khir. **3**: 147, 1925; cited by Judin [2]	1921	M	25	Sarcoma of pelvis	General	Died 23 days later from parotitis and pneumonia
Brzosovski: Novy khir. Arkh. **4**: 179, 1921; cited by Judin [2]	1921	F	16	Sarcoma of femur	General	Alive after 4 mo.; metastasis
Israel, cited by Judin [2]	1921	F	..	Sarcoma	.....	Died ½ hr. later
Schadelmose: Acta chir. Scandinav **53**: 523, 1924	1923	..	..	Chondrosarcoma	.....	Lived 10 mo. or more

TABLE 1.—*Cases of Interpelviabdominal Amputation Reported in the Literature—Continued*

Author	Year	Sex of Patient	Age of Patient, Yr.	Disease	Anesthesia	Result
Judin [3]	1923	F	36	Chondrosarcoma of femur	Spinal	Alive after 2½ yr. or more; gave birth to a child
Rabinovitch: Nov. khir. **3**: 394, 1925; cited by Judin [3]	1925	M	58	Sarcoma of femur	Spinal	Lived 8 weeks
Rabinovitch, cited by Judin [3]	1925	M	49	Sarcoma of femur	Spinal	Died 3 days later
Krassintzev, cited by Judin [3]	1925	M	..	Sarcoma of femur	General	Died 8 days later
Krassintzev, cited by Judin [3]	1925	M	..	Sarcoma of femur	General	Died 30 days later
Krassintzev, cited by Judin [3]	1925	M	..	Sarcoma of femur	General	Died 2 days later
Krassintzev, cited by Judin [3]	1925	M	45	Sarcoma of pelvis	Chloral hydrate	Died 5 hr. later
Krassintzev: Moscow S. Soc. 1925; cited by Judin [3]	1925	M	43	Chondrosarcoma of femur	Spinal	Lived
Kokin, cited by Judin [3]....	....	F	30	Sarcoma of pelvis	Spinal	Died 18 hr. later
Rosanov, cited by Judin [3]..	....	F	27	Tuberculosis	General	Died 6 hr. later
Rosanov, cited by Judin [3]..	....	M	25	Sarcoma of pelvis	Spinal	Alive after 3 mo.; metastasis
Rosanov, cited by Judin [3]..	....	M	50	Sarcoma	Spinal	Died 5 days later
Czerny, cited by Judin [3]....						
Goldberg, cited by Judin [3]						
Abrashanow, cited by Riswasch: Deutsche Ztschr. f. Chir. **238**: 121, 1932	....	F	35	Sarcoma of femur	Spinal	Lived 3 mo. or more
Speed: Ann. Surg. **93**: 167, 1932	Sept. 1931	M	50	Sarcoma of pelvis	Ether	Died at end of operation
Speed: Ann. Surg. **93**: 167, 1932	Oct. 1931	M	45	Sarcoma of femur and pelvis	Spinal	Died 1 hr. later
Gordon-Taylor: Brit. J. Surg. **22**: 671, 1934	1922	M	25	Round-cell sarcoma of femur	Spinal	Died 6 hr. later
Gordon-Taylor: Brit. J. Surg. **22**: 671, 1934	1929	M	17	Osteoclastoma	Spinal	Lived 5½ yr. or more
Gordon-Taylor Brit. J. Surg. **22**: 671, 1934	1933	M	50	Chondrosarcoma of pelvis	Spinal	Lived
Gordon-Taylor: Brit. J. Surg. **22**: 671, 1934	1934	M	28	Sarcoma of pelvis	Spinal	Died 2½ hr. later
Gordon-Taylor: Brit. J. Surg. **22**: 671, 1934	1934	M	18	Sarcoma of femur	Spinal	Lived
Gordon-Taylor: Brit. J. Surg. **27**: 643, 1940	1935	M	17	Sarcoma of muscles of Scarpa's triangle	General	Lived
Gordon-Taylor: Brit. J. Surg. **27**: 643, 1940	1936	F	37	Osteolytic sarcoma of ilium	General	Died a few hr. later
Gordon-Taylor: Brit. J. Surg. **27**: 643, 1940	1937	F	25	Sarcoma of muscles of Scarpa's triangle	General	Lived
Gordon-Taylor: Brit. J. Surg. **27**: 643, 1940	1938	M	14	Sarcoma of right innominate bone	General	Lived
Gordon-Taylor: Brit. J. Surg. **27**: 643, 1940	1938	M	34	Sarcoma of right psoas muscle	General	Died a few hr. later
Gordon-Taylor: Brit. J. Surg. **27**:643, 1940	1939	M	26	Chondrosarcoma of left innominate bone	General	Lived
Fitzgerald: J. Bone & Joint Surg. **18**: 402, 1936	1935	M	13	Osteogenic sarcoma of femur	Spinal	Lived
Leriche and Stulz: Presse méd. **44**: 65, 1936	1935	M	33	Chondromyxosarcoma of pelvis	.....	Lived
Leriche and Stulz: Mém. Acad. de chir. **64**: 31, 1938	1937	M	30	Ewing sarcoma of femur	.....	Lived
Pascalis: Progrès méd., 1936, p. 1481	1936	M	44	Osteosarcoma of pelvis	.....	Lived
Banet and Nobo: Bol. liga contra el cancer **11**: 43, 1936	1936	M	27	Fibrosarcoma of femur	Ether	Lived
Gersh: Sovet. khir., 1936, no. 4, p. 681	1936					

TABLE 1.—*Cases of Interpelviabdominal Amputation Reported in the Literature—Continued*

Author	Year	Sex of Patient	Age of Patient, Yr.	Disease	Anesthesia	Result
Fiero: Cir. y cirujanos **5**: 169, 1937	1936	F	..	Sarcoma of femur	.....	Lived
Fitzwilliams: Proc. Roy. Soc. Med. **31**: 548, 1938	1937	M	62	Rhabdomyosarcoma of vastus internus muscle	.....	Lived
Richard and Clavel: Lyon chir. **35**: 81, 1938	1938	M	36	Sarcoma of femur	Ether	Died
Rapant: Chirurg **10**: 804, 1938	1938	M	29	Osteosarcoma of femur	.....	Lived
Rapant: Chirurg **10**: 804, 1938	1938	M	14	Osteosarcoma of femur	Ether	Lived
Shvart: Vestnik klin. **55**: 57, 1938	1938	M				
Padovani: Mém. Acad. de chir. **65**: 361, 1939	1938	M	18	Myeloma of femur; single trauma	Ether	Lived
Leighton: Bull. St. Louis M. Soc., 1938, p. 87	1935	M	22	Osteochondroma of pelvis	Spinal	Living after 6 yr.
Leighton: Present report..	1939	F	44	Chondrosarcoma of pelvis	Spinal	Lived 2 mo.; pulmonary metastasis
Leighton: Present report..	1941	M	47	Osteosarcoma of ischium	Spinal	Living

and the leg elevated in order to return the blood of the leg into the body, a method suggested by Webb-Jones in 1899. This may be assisted by the application of a Martin bandage. The vessels with parietal peritoneum are readily reflected together with the ureter to the brim of the pelvis. At this point the pubic bone may be separated at the symphysis or divided with a Gigli saw. A Gigli guide or a curved Rochester-Péan forceps is readily passed behind the pubic bone. The Gigli saw is pulled through and the bone divided. By keeping close to the bone there is little danger of injuring the internal pudendal artery.

Second Stage.—With the patient turned on his sound side, a posterior flap from the middle of the crest of the ilium beginning at the first incision is formed by an incision which extends downward over the trochanter major and about 3 inches (8 cm.) below to reach the insertion of the gluteus maximus muscle in the femur. It then curves backward to meet the first incision which has been extended outward in the gluteal groove. The fascia is divided in the same line, and the gluteus maximus muscle is readily exposed, divided at its insertion to the femur and reflected outward. Care must be taken to avoid injury to the superior gluteal artery and nerve, which supply this muscle. When the greater sciatic notch is reached, the piriformis muscle is observed crossing this space. Division of the muscle allows one to recognize the sciatic plexus of nerves and preserve the branches to the gluteus maximus muscle and also the superficial branches of the gluteal artery. The deep branches of the superior gluteal artery which pass under the gluteus medius and gluteus minimus muscles are readily located, ligated and divided, and the corresponding muscles are readily freed from the ilium. Into the sciatic plexus, which is exposed emerging from below the

piriformis muscle, procaine hydrochloride is injected, and it is then divided. The inferior gluteal and internal pudendal arteries are ligated at this time. By separating the iliopsoas muscle from the ilium, a Gigli saw is passed over the ilium through the sacrosciatic notch and the bone divided parallel to the sacroiliac articulation. The remaining attachments are the sacrosciatic ligaments, and the iliopsoas and levator ani muscles, the division of which frees the extremity from the body. The obturator vessels and nerve usually require attention at this point in the operation. The large gluteal flap is brought into place, and the upper portion of the muscle is sutured to the abdominal muscles and the lower portion to the levator ani. The tendon is attached to the remnant of the adductor muscle at the pubis. A drain is placed in the lower angle. A few silkworm gut tension sutures and skin closure with silk or clips complete the operation.

TABLE 2.—*Summary of Diseases for Which Interpelviabdominal Amputation Was Done and Operative Results*

Disease	Patients	Lived	Died	Result Unknown	Operative Mortality Rate
Sarcoma	73	39	34	..	....
Tuberculous osteomyelitis	18	6	12	..	....
Nontuberculous osteomyelitis	6	3	3	..	....
Osteochondroma	2	2	0	..	....
Marjolin ulcer	2	1	1	..	....
Not stated	7	..	1	6	....
Total	108	51	51	6	50%

Table 1 incorporates all the published cases of interpelviabdominal amputation.[7a] The list of Judin contained several reduplications, and a list by Gordon-Taylor had omitted 2 cases reported by Babcock. I have reviewed the original papers so far as possible, and with these corrections I find that the operation has been done 108 times. The cases are arranged according to date of operation, and when more than 1 case has been reported, I have listed the authors in sequence.

In table 2 I have given a brief summary of the diseases for which the amputation was done and the results of the operation.

Geschickter and Copeland [8] in their book on bone tumors published in 1931 collected 155 cases of chondromyxosarcoma. In 8 of these the

7a. Since my paper was submitted for publication, I have found the following references to similar operations: Turner, G. G.: Proc. Roy. Soc. Med. **34**:562, 1941. Selig, S.: J. Bone & Joint Surg. **23**:929, 1941. Whittaker, A. H., and Sobin, D. J.: Ann. Surg. **115**:435, 1942. Morton, J. J.: Ann. Surg. **115**:628, 1942.

8. Geschickter, O. F., and Copeland, M. M.: Tumors of Bone, New York, American Journal of Cancer, 1932.

tumor was primary in the innominate bone. Seven patients died following palliative treatment, such as curettement, excision or irradiation. One was living at the end of twenty months. Among 88 cases of osteosarcoma collected Geschickter and Copeland found only 1 case in which the growth arose in the os pelvis, and in this case the patient did not survive palliative treatment.

On analyzing the 108 cases of interpelviabdominal amputation I find that the operation has been performed for sarcoma 73 times. In 27 cases the disease was primary in the os pelvis. Thirteen patients recovered and lived from two months to five years or more. Fourteen patients died, most of them within a few hours; the mortality rate is thus 51.85 per cent.

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IMPORTANCE AND DISTRIBUTION OF THE TRANSVERSALIS FASCIA FROM THE VIEWPOINT OF THE SURGEON

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The importance of the transversalis fascia can scarcely be exaggerated. How it has escaped the emphasis it deserves is inexplicable. Few anatomists have seen it complete. Fewer surgeons appreciate its existence. Books on anatomy dismiss the graphic description of this relatively all-pervading abdominal tissue with one paragraph. Yet the transversalis fascia in its entirety is second in importance perhaps only to the peritoneum as an encasing membrane of the abdominal contents —now reenforcing, now merging into one with the parietal peritoneal tissue on the one hand and with the abdominal aponeurotic fibers on the other. Where function demands, it thickens and develops its strong elastic fibers to a protective perfection.

The purpose of this paper is to describe in detail the distribution of the transversalis fascia as observed in a large series of dissections on cadavers carried out over a period of seven years. It is likewise desired to emphasize several points not generally appreciated.

Bassini was one of the first to call attention from a surgical standpoint to the importance of the transversalis fascia in the region of the inguinal canal. It was he who emphasized the part played by this fascia in the production and the repair of inguinal hernia. The fibers here are usually strong and form the posterior surface, or surgical floor, of the inguinal canal. They conify (fig. 1) and thicken to produce the internal inguinal ring and descend over the structures of the cord in a funnel-shaped manner to constitute what is known as the infundibuliform fascia.

Superiorly, from the inguinal canal, the fascia spread out laterally and upward, ascending anteriorly over the entire under surface of the abdominal muscular wall until it meets the thin inner fascial covering of the muscles constituting the diaphragm. Here the fibers of the transversalis fascia thin out and join so intimately with the inner fascial lining of the diaphragm that it is extremely difficult to effect separation and at times even confusing to tell definitely which sheath belongs to the proper structure. Patient and painstaking dissection, however, will

Fig. 1.—Candid camera photograph of a dissection of the inguinal region of a cadaver showing the relation of structures to the transversalis fascia.

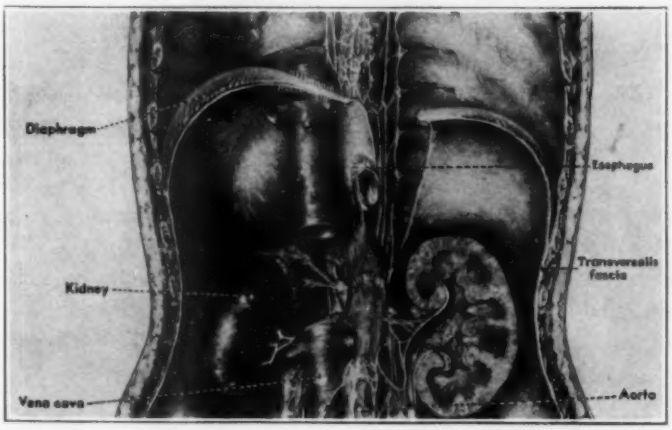

Fig. 2.—Illustration of the hiatal arrangement of the transversalis fascia. The digitation effect was produced by dissection.

reward one with the discovery of how highly specialized the protective function of the transversalis fascia is in this region.

In the center the fibers of the transversalis fascia are strongly attached and are almost one with the central fascia of the diaphragm. At each hiatal perforation, where the thoracic structures pass through to the abdomen, fibers of the transversalis fascia separate. Some ascend through the rent and travel upward several inches, encircling the tubular structures. They conify and completely encircle the perforating structures in a manner not much unlike their enclosure of the cord in the inguinal region. The other fibers descend along the perforating thoracic

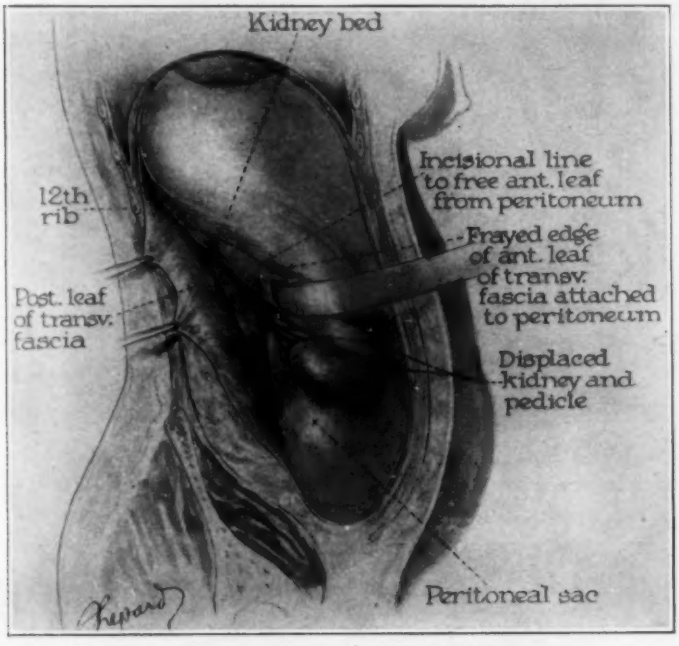
Kidney bed
Incisional line to free ant. leaf from peritoneum
12th rib
Frayed edge of ant. leaf of transv. fascia attached to peritoneum
Post. leaf of transv. fascia
Displaced kidney and pedicle
Peritoneal sac

Fig. 3.—Separation of the transversalis fascia to form Gerota's fascia of the kidney.

structure, likewise encircling it in a funnel-shaped manner. Thus, the aorta, the azygos vein, the thoracic duct, the esophagus and the vena cava, the two greater and lesser splanchnic nerves and the hemiazygos vein are all surrounded and insulated by this encircling process of the transversalis fascia at their diaphragmatic hiatal perforation. The teleology is apparent and assuredly accounts for the relative infrequency of diaphragmatic hernias.

At the xyphoid process the fibers of the transversalis fascia follow the attachment of the diaphragm and merge with the fibers of the falciform ligament of the liver. Here again it is possible by careful and

assiduous dissection to separate the fibers of the transversalis fascia from the falciform ligament, and it is interesting to note the distance to which the former extend before losing their identity with the ligamentous tissue.

Posteriorly the fibers of the transversalis fascia descend over the diaphragmatic crura, giving off fibers of attachment to the lumbar vertebrae and their transverse processes and merging laterally with the aponeuroses of the psoas major and the quadratus lumborum muscles. At a level just superior to the adrenal gland the fascia splits off an

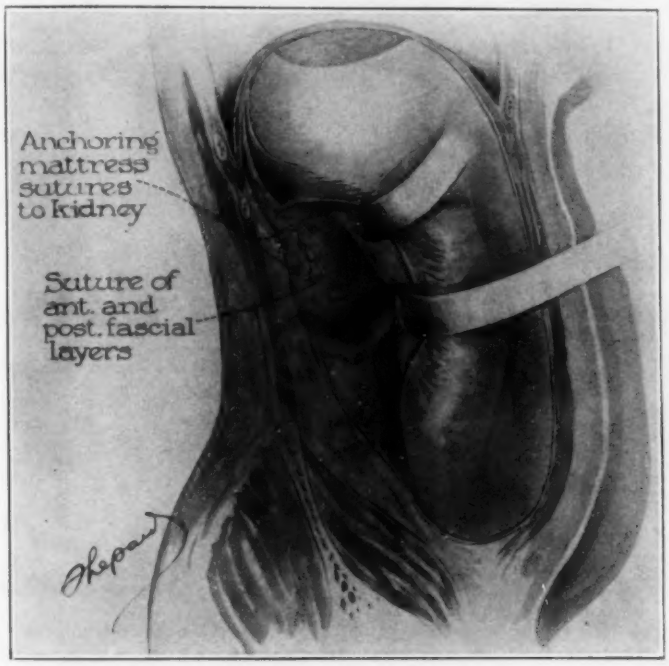

Fig. 4.—Utilization of the transversalis fascia for the surgical correction of a "floating" kidney (my method).

internal sheath which passes forward in front of the kidney and its vessels (fig. 3). This anterior sheath and the posterior sheath that descends over the psoas and quadratus muscles completely encase the kidney and form what is known as Gerota's fascia. Thus the role of the transversalis fascia is a particularly important one in the formation of the renal fossa and in the maintenance of a more or less fixed position of the kidney.

Obviously, from a surgical standpoint it can be seen that a wandering kidney is the result of imperfect fusion or relaxed attachment of this specialized structural arrangement of the transversalis fascia. The

anterior sheath is defective in its enclosing property and consequently permits the kidney to fall out of its bed. As a result, a method for nephropexy has been devised (fig. 4) the fundamental principle of which consists in simply suturing together the anterior and posterior layers of this fascia and fixing the renal capsule to one or both fascial sheaths.

If the dissection is continued posteriorly, it is possible to trace the transversalis fascia on down into the pelvis (fig. 5). Here, laterally, the fibers become almost inseparable with the aponeurotic covering of the iliac fossa, where again the fascia becomes highly specialized and warrants a separate description in all books on anatomy, under the

Fig. 5.—Relation of the transversalis fascia to the pelvic structures (modified from Campbell): *A*, obturator fascia; *B*, ischiorectal fascia; *C*, rectovesical fascia.

term pelvic fascia. It forms the tendinous arch, or "white line," of the pelvis (fig. 6) by separating into several conspicuous layers, the outermost one of which is the fascial sheath of the obturator internus muscle, the obturator fascia, and loses itself by attaching to the tuberosity of the ischium. It is attached to the pubic arch and blends with the corresponding layer of the opposite side to form the posterior layer of the triangular ligament. The second, or middle, sheath, the ischiorectal fascia, lines the under surface of the levator ani muscle, while the innermost sheath constitutes the rectovesical fascia and extends downward and inward over the upper surface of the levator ani muscle, thus completely encapsulating this structure. It then invests the bladder, the prostate and the rectum. It is the anterior and lateral reflec-

tion, or true ligament, of the bladder. It is the capsule of the prostate and covers the seminal vesicles and ducts (fig. 7). Ascending, it attaches to the inferior border of the symphysis pubis.

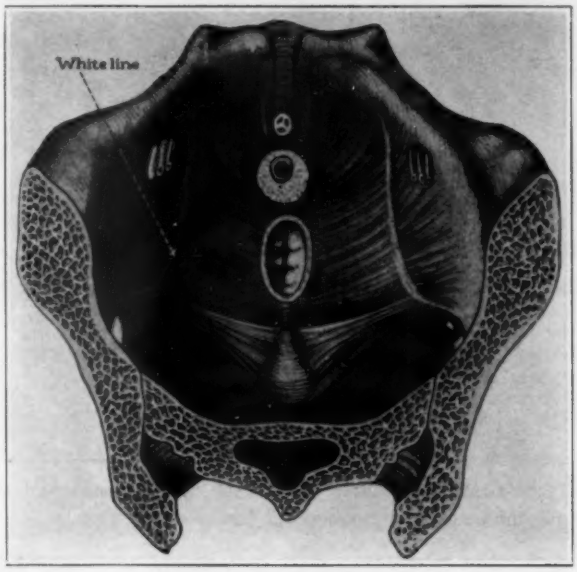

Fig. 6.—Relation of the "white line" of the pelvis to the pelvic diaphragm (modified from Campbell, W. F.: A Textbook of Surgical Anatomy, Philadelphia, W. B. Saunders Company, 1921).

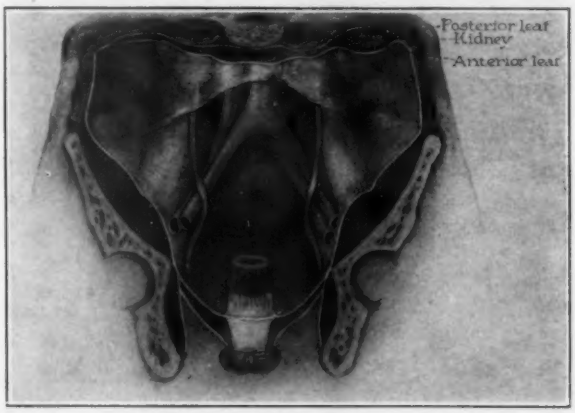

Fig. 7.—Artist's reproduction illustrating the distribution and continuity of the transversalis fascia in the pelvis—the pelvic fascia. Note the anterior and posterior leaves of the transversalis fascia forming the renal fascia.

In a woman this innermost layer, which connects the rectum and the bladder, is perforated by the vagina and the urethra; as at the

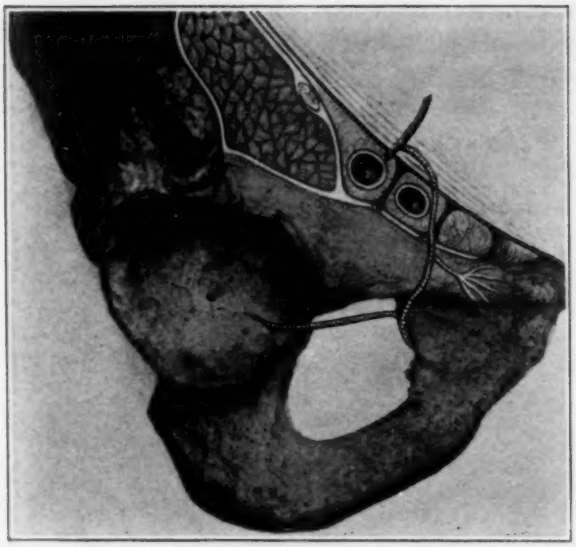

Fig. 8.—The crural arch. Note the fascial compartments and the protective arrangement for the empty space (modified from Campbell).

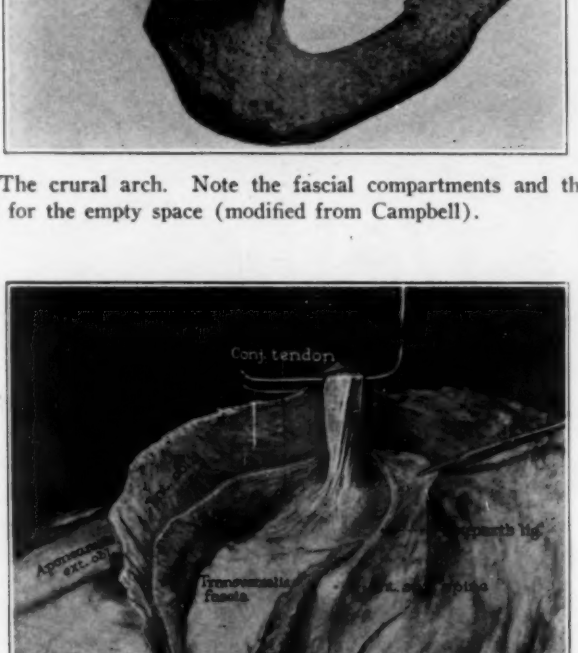

Fig. 9.—Candid camera photograph of a dissection of the inguinal region showing the relation of the transversalis fascia to Poupart's ligament. Note fibers of attachment to Poupart's ligament.

sites of other perforating organs, the fibers encircle and conify these structures, sealing off all possible exit for the pelvic organs. A disturbance in the continuity of these fibers will explain surgically the formation of perineal herniations, such as cystocele, urethrocele and rectocele.

Continuing the dissection superiorly, one finds that the fibers ascend over the posterior surface of the symphysis pubis and laterally merge with the iliopectineal fascia. Here the transversalis fascia plays an important part in relation to the structures associated with the crural arch (fig. 8). It conifies the large vessels and nerves that pass out on to the leg in an identical manner as the structures perforating the diaphragm. The fascia splits into two divisions, one ascending along the structure and the other descending, completely insulating the vessels and walling off any possible exit for an abdominal viscus. The fascia continues out to the leg, contributing to the formation of the fascia of that structure. At the femoral ring, or so-called empty space of the crural arch, the fibers of the transversalis fascia make a somewhat rosette-like arrangement that completely encloses this portion of the crural arch. Practically it can be seen that a femoral hernia at this point is acquired only by a defect in this arrangement of the fibers or by a break in their continuity. The transversalis fascia on leaving the structures beneath the crural arch gives off slivers of attachment to the inguinal ligament (fig. 9) and then spreads out to form the surgical floor of the inguinal canal, as has been described at the beginning of this paper. The description applies to both halves of the abdominal wall, and the fascia produces a continuity far beyond the expectation of the surgeon and the anatomist.

COMMENT

Some may dispute the nomenclature. This, however, is purely an academic question. It is conceded that it is a question for discussion. The fact remains that there is a structure in continuity with the structure admittedly called the transversalis fascia in the inguinal region and that this structure is distributed as narrated, whether one wishes to call it intra-abdominal fascia, Gerota's fascia, pelvic fascia or any other name. To restrict it, however, to the posterior sheath of the transversalis muscle, i. e. the transversus abdominis muscle, is definitely out of order and throws on the proponents of this theory the necessity of explaining, for example, the continuity of the fascia of the pelvis or the diaphragm.

Pedagogically, I believe a step forward could be taken by considering the fascia as an entity, as a simple continuity to which specific

names are affixed according to the specific location or function demanded of it (fig. 10). Assuredly it is against all principles of good pedagogy to fail to recognize the structure as a unit, generally distributed throughout the abdomen and the pelvis, and to describe it as a disjointed entity only, separate, distinct and restricted to a specialized location or property which it possesses.

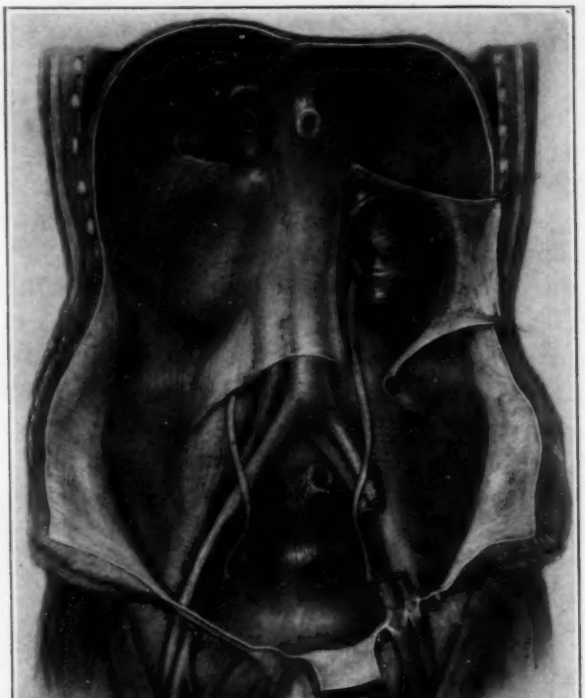

Fig. 10.—Artist's illustration of a dissection showing complete distribution and continuity of the transversalis fascia throughout the body. Note the encircling fibers about the structures that enter and leave the abdominal cavity.

SUMMARY

The distribution of the transversalis fascia is narrated as observed in a large series of dissections on cadavers.

Emphasis is placed on certain not generally appreciated structural features and on their teleologic function.

The possible utilization of the fascia in surgery and the advisability of a modified nomenclature are discussed.

30 North Michigan Avenue.

CHEMICAL CAUTERIZATION OF THE MUCOSA OF THE GALLBLADDER

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AND
C. FREMONT VALE, M.D.
DETROIT

Every surgeon occasionally finds it necessary to operate because of a diseased gallbladder when in his judgment something less than classic cholecystectomy is indicated. There are two types of patients in whose cases the decision to perform a less severe operation is important. These are: (1) persons whose general condition make the risk of cholecystectomy too great and (2) persons for whom removal of the gallbladder is hazardous because of the local lesion. In many clinics cholecystostomy is the operation performed in this group of patients; in others some form of partial cholecystectomy or cauterization is resorted to. Thorek [1] advised excision of most of the free portion of the wall of the gallbladder and electrocoagulation of the part attached to the liver. During the years 1935 to 1940 we have used cauterization of the mucosa of the gallbladder with solutions of phenol and alcohol, the procedure often called chemical cholecystectomy, as a preferred method for those patients in whom cholecystectomy seemed unwise. We have done this in the hope that it would prove more successful than cholecystostomy which in our experience is so often followed by a recurrence of symptoms and pathologic changes similar to those originally present.

The application of chemicals to the mucosa of the gallbladder in an attempt to destroy it is not new. As early as 1921 and again in 1926, Martin [2] presented a total of 7 cases in which acute cholecystitis in poor surgical risks was treated with incision of the gallbladder from the fundus to the cystic duct and application of iodine followed by drainage. He was convinced that this procedure absolutely destroyed

From the Department of Surgery, Wayne University College of Medicine, and City of Detroit Receiving Hospital.

1. Thorek, M.: Modern Surgical Technic, Philadelphia, J. B. Lippincott Company, 1938, vol. 3, pp. 1580-1597.

2. (*a*) Martin, E. D.: Cholecystostomy vs. Cholecystectomy, New Orleans M. & S. J. **74**:4 (July) 1921; (*b*) Complete Cholecystostomy vs. Cholecystectomy in Cases of Empyema of Gall Bladder, South. M. J. **19**:198 (March) 1926.

the gallbladder. Likewise, Thompson, discussing Martin's second paper,[2b] stated: "The mucous membrane probably sloughs out during convalescence." Apparently these patients were cured at least for the follow-up period.

In 1928 Pribram [3] described mucoclasis, the procedure being similar to that of chemical cholecystectomy.

In 1927 Gatch [4] first mentioned chemical cholecystectomy. In 1930 he [5] reported 54 cases in which this treatment was used. Fifteen of these were cases of gangrenous cholecystitis. There was 1 death; apparently there was no recurrence of symptoms in the other cases. He was convinced of the ease with which the operation could be done in the presence of acute inflammation and the small risk to the patient. The indications included: (1) gangrenous cholecystitis; (2) a gallbladder densely adherent to surrounding structures; (3) broad attachment of the gallbladder to the liver; (4) a patient who is a poor risk. Our experience with the procedure described by Gatch for the period 1935 to 1940 is reviewed. We have studied also the effects of chemical cauterization of the mucosa of the gallbladder in dogs and in swine.

The technic we have used is similar to that described by Gatch. The fundus of the gallbladder is opened; the bile is aspirated, and any stones present are removed. Usually a portion of the free edge of the gallbladder is then excised, and the remainder of the mucosa of the gallbladder is treated with from four to six applications of 95 per cent solution of phenol each of which is followed by an application of 95 per cent solution of alcohol and drying with a sponge. No attempt is made to block the cystic duct. The phenol and the alcohol are allowed to gravitate well into the ampulla of the gallbladder. A soft rubber tube is inserted down to the ampulla, and the remnant of the gallbladder is folded and sutured about this tube which emerges through the fundus and is allowed to drain for eight to ten days. No further drainage of the abdominal cavity is done. This technic does not alter any procedure which might be necessary on the common duct or any other intra-abdominal viscus.

During the past five years we have had occasion to perform this operation in 47 cases. In general we were pleased with the smooth convalescence of the patients in spite of the acute process found at

3. Pribram, B. O.: Treatment of Gall Bladder by Mucoclasis, Med. Klin. **24**:1147, 1927-1928.

4. Gatch, W. D., in discussion on Bruggeman, H. O.: Treatment of Acute Cholecystitis, Tr. West. S. A. (1927) **37**:345, 1928.

5. Gatch, W. D.: Chemical Cholecystectomy, Tr. South. S. A. (1929) **42**:110, 1930.

operation. Elderly people tolerated it especially well. In no case did a fistula persist.

In 6 of the 47 cases mentioned the operation was combined with exploration of the common duct.

Four (8 per cent) of the 47 patients died in the hospital. Of these 4, 3 were poor risks with an acute process. The fourth had a gastric resection in addition and died from a complication of that operation.

As we approached the end of the five year period and these patients were doing well clinically, it seemed that the mucosa of the gallbladder

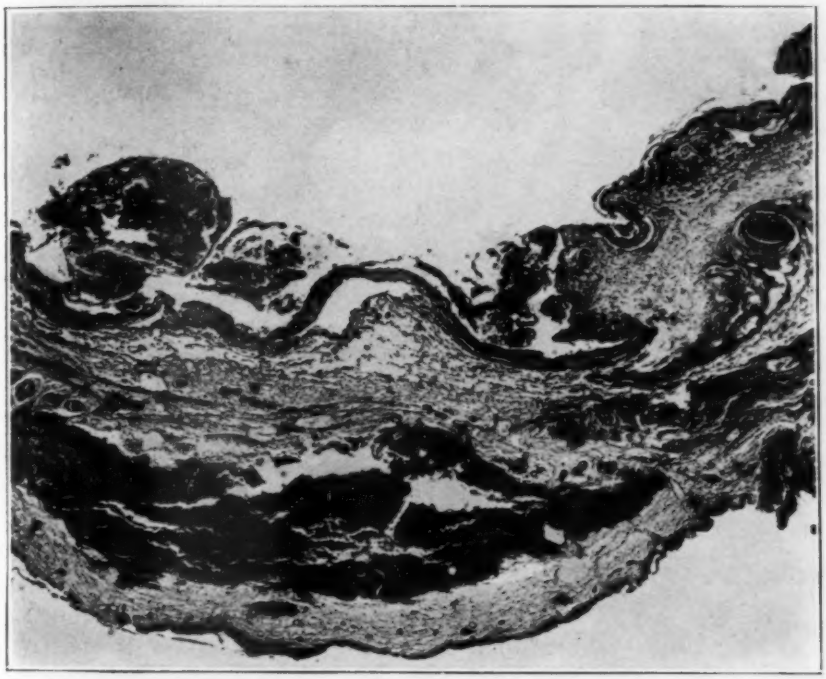

Fig. 1.—Photomicrograph of the wall of a dog's gallbladder two weeks after cauterization with phenol and alcohol, showing apparently complete necrosis of all coats.

must certainly be completely destroyed by this procedure. It was only when postoperative Graham-Cole examinations began to show visualization of the gallbladder that we decided to investigate more thoroughly.

In a follow-up of the remaining 42 patients we were able to make contact with 34. The average time since operation amounted to a little less than four years. Of these 34 patients, 29 (85 per cent) stated that they had had no recurrence of symptoms similar to those which

they had previous to operation and that there was no new symptom which related to the gallbladder. These were classed as good results. Three other patients stated that they remained free from symptoms if they were careful of their diet. However, they were troubled especially by greasy foods, cabbage and onions. These patients thought that they were improved since operation but that the result was not entirely good. They amounted to 8.8 per cent of the patients followed. There were 2 patients, or 6.2 per cent, who reported their condition as about the same. One of these, later operated on again, was admitted two years

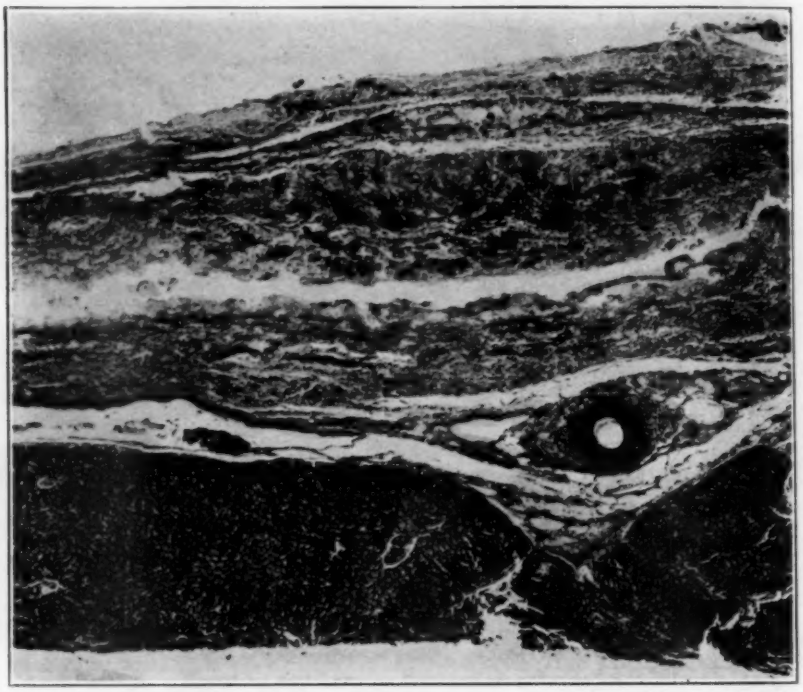

Fig. 2.—Photomicrograph of the wall of a dog's gallbladder fourteen weeks after cauterization with phenol and alcohol, showing well defined organization of the wall and disappearance of necrotic debris.

after chemical cholecystectomy with only mild pain in the right upper quadrant of the abdomen without evidence of an acute process. A Graham-Cole test did not show a functioning gallbladder. Reoperation revealed part of the omentum adherent to the liver and the bed of the gallbladder. Dissection disclosed a remnant of gallbladder 1¼ inches (3.2 cm.) long with a lumen of ½ inch (1.27 cm.). The mucosa was

grossly atrophic. No stones were present. Microscopic examination (fig. 7) showed complete regeneration of both glandular and surface epithelium.

Of the 34 patients with whom contact was made, 18 had Graham-Cole examinations from six months to four years after operation. Regardless of symptoms, the gallbladders of these 18 were visualized

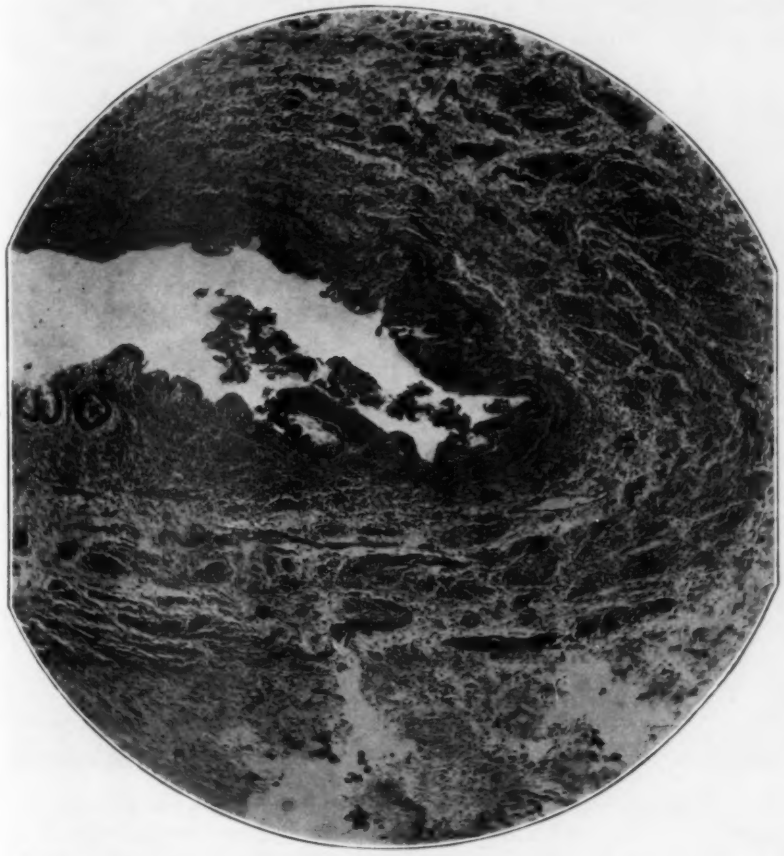

Fig. 3.—Photomicrograph of the wall of a dog's gallbladder six months after cauterization with phenol and alcohol, showing the structure. The picture suggests that the glands of Lushka develop first and the surface epithelium appears later, probably originating from glandular epithelium.

in varying concentrations of the dye in 7 (39 per cent). It is interesting to note that some of the gallbladders which did not function previous to operation were now visualized.

EXPERIMENTAL STUDY

As reoperation is not common enough to allow a careful histologic study on human beings, animal experimentation has been substituted. The routine chemical cauterization as already described was carried out on both dogs and swine, with a total of 14 animals. Specimens were taken from the gallbladder before and just after cauterization with phenol and alcohol and at intervals from two to sixteen weeks in the dogs and from five weeks to eighteen months in the swine. At autopsy,

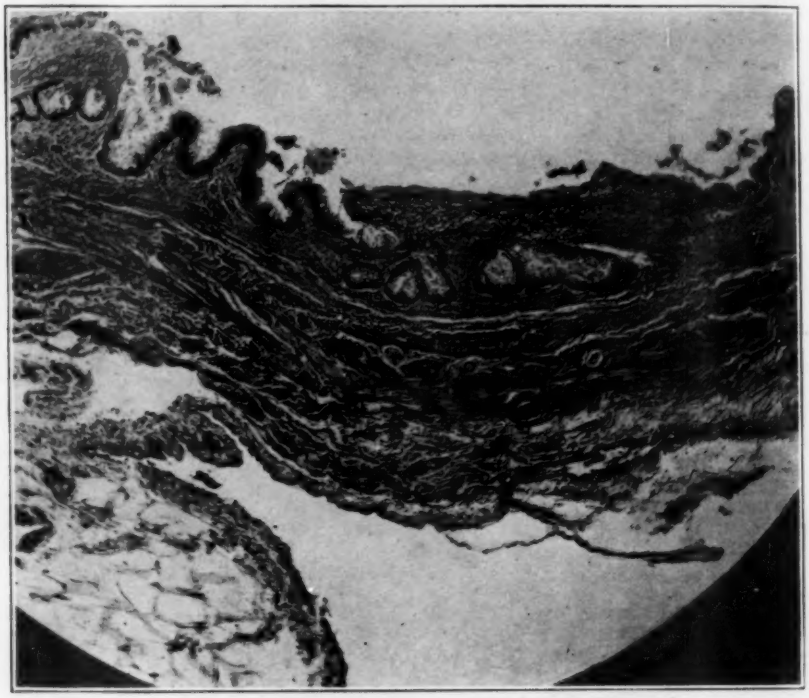

Fig. 4.—Photomicrograph of the wall of a dog's gallbladder nine months after cauterization with phenol and alcohol, indicating partial reconstruction of the mucosa. Some residual chronic inflammatory thickening of the wall is present.

in the majority of the animals the gallbladder was found to be extremely small but occasionally it approached normal size. Although hard to locate in some cases, a gallbladder lumen has always been present. In none of these have there been any stones or evidence of injury to the common duct or the liver.

In the many sections examined the picture was uniform, depending only on the length of the postoperative period. Immediately after

cauterization there was acute necrosis with apparently complete loss of epithelium and with congestion, edema and hemorrhage through the deeper layers. At the end of two or three weeks there was organization and occasionally formation of a small abscess in the wall. Often a few distended glands can be seen. By the tenth to the fourteenth week the epithelium was regenerated, although there was still infiltration of

Fig. 5.—Photomicrograph of a dog's gallbladder ten weeks after cauterization with Carnoy's solution. Apparently complete necrosis has taken place.

round cells and polymorphonuclear cells in the submucosa. At six to nine months the mucosa appeared fairly normal except for some fibrosis in the deeper layers (figs. 1, 2, 3 and 4).

In a further attempt to destroy the mucosa a similar procedure was carried out on the animals with the use of Carnoy's solution. This is

a strong cauterizing agent containing absolute alcohol, chloroform and glacial acetic acid and is used as a rapid fixative solution for pathologic specimens. According to this technic the abdomen is opened and the gallbladder isolated. A large caliber needle is inserted into the lumen of the gallbladder and the bile aspirated. The gallbladder is then irrigated with solution of sodium chloride until practically all the bile

Fig. 6.—Photomicrograph of a pig's gallbladder ten months after cauterization with Carnoy's solution. Development of glands is better than that of surface epithelium, which, however, is well regenerated.

has been removed. Enough Carnoy's solution is then instilled to fill the gallbladder, and this is allowed to remain until the serosa turns dark. This usually takes from three to four minutes. At the end of the time the Carnoy solution is aspirated. However, whatever remains on the wall of the gallbladder is not removed by irrigation.

The animals all survived this procedure, although at the time of operation the gallbladder was thoroughly fixed with the solution. Specimens of these gallbladders were taken ten weeks (fig. 5) to ten months later.

The reaction of the mucosa of the gallbladder following the procedure just described was much the same as that following the application of phenol and alcohol. Figure 6 shows a section from the gallbladder of a pig ten months after cauterization with Carnoy's solution. The mucosa was apparently fully regenerated. Some glands extended deep into the wall. There were a few areas of phagocytosed hemosiderin representing old hemorrhage.

Fig. 7.—Photomicrograph of a human gallbladder two years after cauterization with phenol and alcohol. The mucosa is fairly well restored.

SUMMARY

Chemical cholecystectomy has been carried out on 47 human beings, and the clinical results are reviewed.

Graham-Cole studies have been made postoperatively, and the results are shown.

Experimental cauterization has been carried out on animals both with phenol and alcohol and with Carnoy's solution, and the findings in these studies are given.

CONCLUSIONS

In cases in which a less severe operation than removal of the gallbladder is judged to be indicated, chemical cauterization of the mucosa is followed by a lower rate of recurrence of symptoms than cholecystostomy.

Despite extensive chemical cauterization, the mucosa of the gallbladder regenerates rapidly. It appears that some of the deeper glands in the wall survive and become the source of new epithelium.

The term chemical cholecystectomy is a misnomer, because the gallbladder is not completely eliminated as a functioning organ.

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LYMPHOSARCOMA OF THE INTESTINE

REPORT OF TWO CASES

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DAVID G. MASON, M.D.

AND

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The relative rarity of tumors of the small intestine as compared with their frequency in the stomach and the large intestine is a common observation. It is further noted that the clinical manifestations of tumors in the stomach and the colon are more definite and readily recognized, while similar lesions in the small bowel are usually furtive and obscure, present variable and vague symptoms and even though suspected are found only by exploratory operations or at autopsy. This is true of lymphosarcoma, which, however, is one of the more common sarcomas of the gastrointestinal tract.

Although obscured by inaccurate terminology, certain well recognized types of sarcoma of the small bowel have been recorded. Speese,[1] in a summary of 99 different sarcomas of the small intestine, recorded the following types, in the order of their frequency; round cell sarcoma, 43; lymphosarcoma, 34; spindle cell sarcoma, 13; fibrosarcoma, 3; myxosarcoma, 2; myosarcoma, 2; mixed cell sarcoma, 1; melanotic sarcoma, 1.

It will be observed that the incorrect choice of terms used in pathologic diagnosis leaves the identity of types open to question. One must consider the possibility and the probability of lymphosarcoma and so-called round cell sarcoma being one and the same lesion.

INCIDENCE

Baltzer[2] was unable to find a single instance of lymphosarcoma at the Berlin Pathologic Institute, Berlin, Germany, during the period 1859 to 1875. In 1900 Libman[3] noted 59 instances and commented on the

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Read at the annual meeting of the Seattle Surgical Society, Jan. 24, 1942.

From the Department of Pathology, University of Oregon Medical School, and St. Luke's Hospital, San Francisco.

1. Speese, J.: Sarcoma of the Small Intestine, Ann. Surg. **59**:727, 1914.

2. Baltzer, M.: Ueber primäre Dünndarmsarcome, Arch. f. klin. Chir. **44**:717, 1893.

3. Libman, E.: Sarcoma of the Small Intestine, Am. J. M. Sc. **120**:309, 1900.

infrequency of this tumor, pointing out that Smoler,[4] at the Pathologic Institute at Prague, Czechoslovakia, found only 13 cases of lymphosarcoma among 13,036 autopsies over a period of fifteen years. Nothnagel,[5] of Vienna, Austria, found only 12 instances of all varieties of intestinal sarcoma over a period of twelve years. Müller[6] was cited as observing only 1 instance of lymphosarcoma of the intestine in 102 cases of sarcoma of various kinds. Lecène[7] found enough additional cases to make the total of 89. Warthin[8] found only 2 lymphosarcomas of the intestine among 2,000 malignant neoplasms in young persons (1 to 30 years of age). Graves,[9] in a thorough search of the *Index Medicus* (encumbered by inaccurate terminology), concluded that there were 246 fairly authentic instances; to these he added 3, making a total of 249. Ulman[10] found 126 instances; these he added to the 249 reported by Graves to make a total of 375 instances of primary lymphosarcoma of the intestine. Cheever[11] recorded 16 verified instances of primary lymphosarcoma of the stomach and the intestine in a hospital of two hundred and forty beds over a period of nineteen years; during this time 976 patients entered with tumors of the stomach and the intestine. Of the 16 lymphosarcomas, 9 were in the stomach and 7 in the intestine. LaBree[12] reported a case of primary lymphosarcoma of the small intestine in a patient aged 51. This made approximately 376 cases of lymphosarcoma of the small intestine specifically recorded in the literature.

Our own experience with this type of tumor revealed only 1 among 38,076 surgical tissues and 11,446 autopsies. Another was encountered by one of us (D. G. M.) shortly after the first made its appearance. The unusual occurrence and the similarity in appearance and location as well as in the clinical manifestations seem to us to be worthy of record.

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4. Smoler, F.: Zur Kenntnis der primären Darmsarkoms, Prag. med. Wchnschr. **23**:135, 1898.

5. Nothnagel, H.: Die Erkrankungen des Darms und Peritoneum, Vienna, A. Hölder, 1898.

6. Müller, W.: Ueber Polyposis intestini mit besonderer Berücksichtigung des Röntgenbefundes, Beitr. z. klin. Chir. **119**:683, 1920.

7. Lecène, P.: Les tumeurs malignes primitives de l'intestin grêle: jéjunoiléon, Thesis, Paris, no. 196, 1904.

8. Warthin, A. S.: The Occurrence of Malginant Neoplasms in the Young, Arch. Int. Med. **15**:444 (March) 1915.

9. Graves, S.: Primary Lymphoblastoma of the Intestine, J. M. Research **40**:415, 1919.

10. Ulman, A., and Abeshouse, B. S.: Lymphosarcoma of the Small and Large Intestines, Ann. Surg. **95**:878, 1932.

11. Cheever, D.: Clinical Aspects and Treatment of Primary Lymphosarcoma of the Stomach and Intestines, Ann. Surg. **96**:911, 1932.

12. LaBree, R. H.: Small Bowel Tumors with Case Report of Lymphosarcoma of the Small Bowel, to be published.

REPORT OF CASES

CASE 1.—R. E. H., a 42 year old married man, was first observed on May 21, 1938. He stated that ever since childhood he had had bilious attacks associated with nausea and vomiting. He complained of a tired feeling of a year's duration. Three months before consultation he began to have distress in the bowel, usually in the right side rather high up but sometimes also in the middle or even the lower part of the abdomen. The discomfort occurred several hours after meals and consisted of a dull ache which occasionally became a rather sharp uncomfortable pain. There was definite tenderness and increased resistance of the right side of the abdomen; occasionally an indefinite mass was felt. There were also a slight trace of sugar in the urine and some secondary anemia (hemoglobin

Fig. 1 (case 1).—Roentgenogram (Dr. Dorwin Palmer) showing the character of the defect in the lower end of the ileum. Note the funnel-shaped obstruction and rarefaction at *I*.

content 94 per cent). The serologic test for syphilis gave a negative result. A roentgenogram revealed the terminal 8 inches (20 cm.) of the ileum to be somewhat dilated, giving evidence that a partial obstruction occurred distal to this area (fig. 1). The mucosa of the terminal portion of the ileum was mottled, suggesting an active inflammation. On the basis of these observations, it was believed that the patient had regional ileitis affecting the terminal portion of the ileum and producing partial obstruction. Surgical treatment was recommended.

The patient entered the hospital on May 24. He offered the additional information that he had suffered from chronic constipation, for which he took many laxatives over a long period. He also lost 5 or 6 pounds (2.3 to 2.7 Kg.).

The physical examination disclosed localized tenderness with increased muscular resistance in the right lower quadrant of the abdomen. On May 27 the abdomen

was opened through a right rectus incision. Some blood-stained fluid was found in the peritoneal cavity. There was also observed a mass occupying the terminal part of the ileum and the cecum, the lesion being confined chiefly to the last couple of inches of the ileum and the region of the valve. A rosette-like excrescence the size of a silver quarter projected from the anterior surface of the cecum. It was smooth but had a lobulated appearance and a deep reddish color. A portion was removed for biopsy. A few moderately large discrete soft nodes were found in the mesentery. The subserosal vessels were tortuous, dilated and filled. There

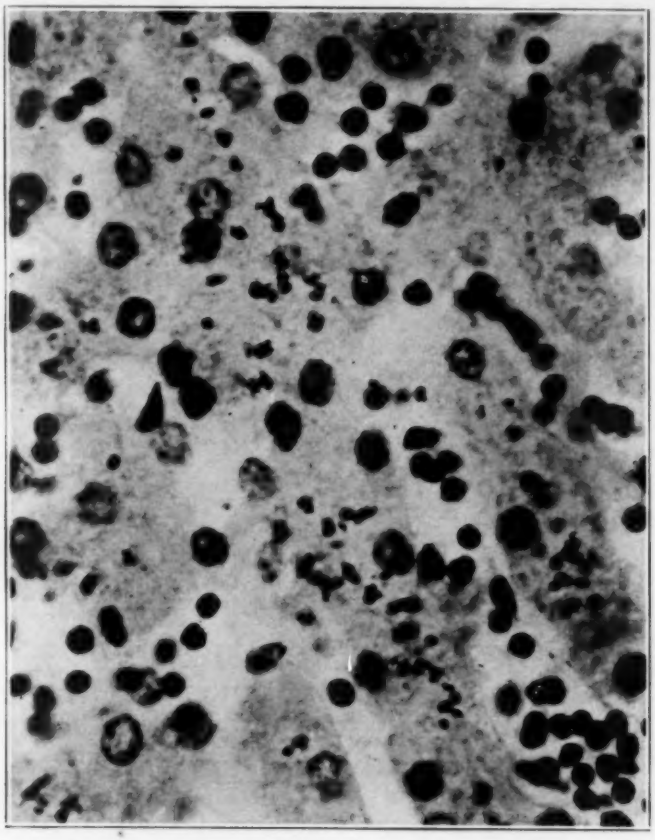

Fig. 2 (case 1).—Photomicrograph illustrating the lymphoblastic or reticulum-like character of the cells of the tumor.

were considerable contraction and apparent scarring of the cecum. The small intestine proximal to the involved area was not markedly distended. The ileum was cut 7 inches (18 cm.) from the ileocecal valve, and the proximal end was then anastomosed to the transverse colon in an isoperistaltic direction. The patient's condition did not warrant complete removal at that time. After the operation the patient's temperature was elevated to 101 F. at times during a period of about ten days, after which it returned to normal.

A restorative regimen with two blood transfusions was carried out. On June 17 the patient was returned to the surgical service (Dr. George Pfeiffer). The loop of the ileum was found plastered against the closed-off terminal portion of the ileum.

There was noted a small abscess between several of the loops of bowel, and perforation had occurred into the attached loop of the ileum. Three other tumor excrescences were seen projecting from the cecal wall. All were similar to the one first partially removed for biopsy. The ileocolostomy opening was found intact. Because of the adhesions and the perforation, the entire mass, consisting of the terminal part of the ileum, the cecum and a portion of the ascending colon, was removed, as was also the remainder of the ascending colon, including the hepatic flexure and the site of the recent ileocolostomy. The ends of the uninvolved parts of the ileum and the colon were then sutured together for a distance of

Fig. 3 (case 1).—Photograph showing one of the surfaces made by sectioning the lower end of the ileum and the cecum. *C*, cecum; *I.V.*, ileocecal valve; *T*, tumor; *I.*, ileum.

several inches, and both ends were brought out of the upper end of the incision. The patient was given 500 cc. of citrated blood at this time and a similar transfusion five days later. On August 26 the ileocolostomy opening was established. Because of chronic spasms the anal sphincters were also dilated at this time.

Gross examination of the first tissue removed for diagnosis revealed it to be rather firm, rubbery, somewhat lobulated, 3 cm. in length, 2 cm. in width and 1.5 cm. in thickness. Externally it had a glistening gray-tannish appearance, but on section it was uniformly gray to grayish white, except for small punctate brown knobs, presumably hemorrhages.

Microscopic examination revealed the following picture: There was an atypical capsular inclusion, presumably thickened peritoneal covering. The cellular tissue beneath this was of a peculiar type. The cells were monomorphic and variable in size, closely apposed to one another and having vesicular ovoid nuclei. The nuclei occasionally contained single nucleoli. Condensations of chromatin in the periphery of the nuclei could be seen. Mitotic figures were numerous. There were no so-called Hodgkin, or Sternberg-Reed, cells or eosinophils present. The cells were distinctly lymphoid, largely of the reticulum type. Mature lymphocytes were sparse. At one point within the so-called capsule there were two discrete nests of tumor cells. These appeared to lie within the capillaries or the lymphatics (fig. 2).

The pathologic diagnosis was highly malignant lymphosarcoma.

At gross examination of the tissue removed later (June 17) there were several specimens. One consisted of 12 cm. of the terminal part of the ileum and the attached appendix. Located 3 cm. proximal to the ileocecal valve was a relatively large annular slightly fungated tumor mass that encircled the lumen and the wall of the entire bowel. It lay largely in the angle between the ileum and the cecum and measured 7 cm. in length (fig. 3). In certain areas it was seen to have invaded the muscularis through to the subserosa. Here considerable hemorrhagic indurated inflammatory tissue was found on the external surface of the bowel. Sectioning portions of the tumor disclosed uniformly white homogeneous surfaces in which no hyperemia or visible necrosis was apparent. The other tissue consisted of 12 cm. of ascending colon and a small loop of small intestine that was anastomosed to the colon. About the anastomosis there was considerable kinking of the small bowel with some acute and chronic regional peritonitis.

Microscopic study of sections of the primary growth present in the terminal part of the ileum showed it to consist of cells similar in all respects to those described in the report of the previous biopsy.

The pathologic diagnosis was primary lymphosarcoma of the terminal part of the ileum, polypoid prolapse of ileac mucosa, hyperplasia of the mesenteric lymph nodes and healed ileocolostomy wound.

The patient left the hospital in good condition on October 26, after one hundred and fifty-five days of hospitalization. He returned to the tumor clinic one month later for further consideration of his treatment. The radiologist considered that roentgen therapy would be more injurious to the intestinal mucosa and surrounding tissues then it would be beneficial in destroying any portion of the possibly remaining tumor.

The patient was kept under periodic observation. There was apparent restoration of health (39 pounds [17.7 Kg.] gain in weight while he was at work). At the time of writing, four years after operative removal, there is still no evidence of recurrence.

Case 2.—J. D., a 17 year old white male high school student, entered St. Luke's Hospital, San Francisco, on Dec. 12, 1938. His chief complaint was flatus and constipation. Three weeks prior to admission flatus with abdominal distention and pain of a griping nature began to develop. This condition was associated with poor bowel movements of diminishing volume with complete cessation for three or four days following a meal of barium sulfate November 29. Six days later he had a good bowel movement free from blood or mucus. Two days after this the previous symptoms again developed; they terminated with nausea and vomiting the night before admission.

Physical examination disclosed a well nourished and well developed young man who appeared acutely ill. The abdomen was tympanitic, rigid and tender. There was also slight secondary anemia (hemoglobin content 93 per cent). All other findings were normal.

Roentgen Examination.—A flat plate roentgenogram of the abdomen showed several dilated loops in the midportion of the ileum. The cecum was distended with flatus. The radiologist concluded that there was no obstruction of the bowel in the ileocecal region. The patient's temperature fluctuated between 37.5 and 38.4 C. (99.5 to 101.12 F.), while the pulse rate varied between 105 and 125. Examination of the blood revealed leukocytosis, the white cell count being 12,000

Fig. 4 (case 2).—Photograph disclosing the site of the tumor projecting into the cecum (*C*). The ileocecal valve fold (*I.C.V.*) seems to overlie part of the tumor; the ileum (*I*) seems to project upward.

with 78 per cent polymorphonuclears, 1 per cent eosinophils and 20 per cent lymphocytes. The patient was operated on the day of admittance by Dr. G. D. Delprat. A large nodular tumor was found in the ileocecal valve. It projected into the cecum. Several large loose hyperemic and edematous lymph nodes were found in the mesoappendix. The cecum, the ascending colon and the terminal part of the ileum were brought out through the incision, which was closed down around the projecting bowel. All of this tissue was enclosed in a rubber glove. A catheter was put into the cecum through one of the fingers of the glove. On December 10, three days later, the projecting loop of the intestine was removed with the cautery. The patient became afebrile two days later. He remained

so for eighteen days, after which a transitory temperature of 102.0 F. occurred and continued for two days. He was discharged on Jan. 23, 1939, clinically improved.

Gross examination by one of us (D. G. M.) yielded the following data: The surgically removed tissue consisted of 12 cm. of the terminal part of the ileum and 14 cm. of the cecum and the ascending colon with the appendix attached. Over the external surface of all these structures there was an abundance of yellowish gray to red purulent material. There was present a new growth in the vicinity

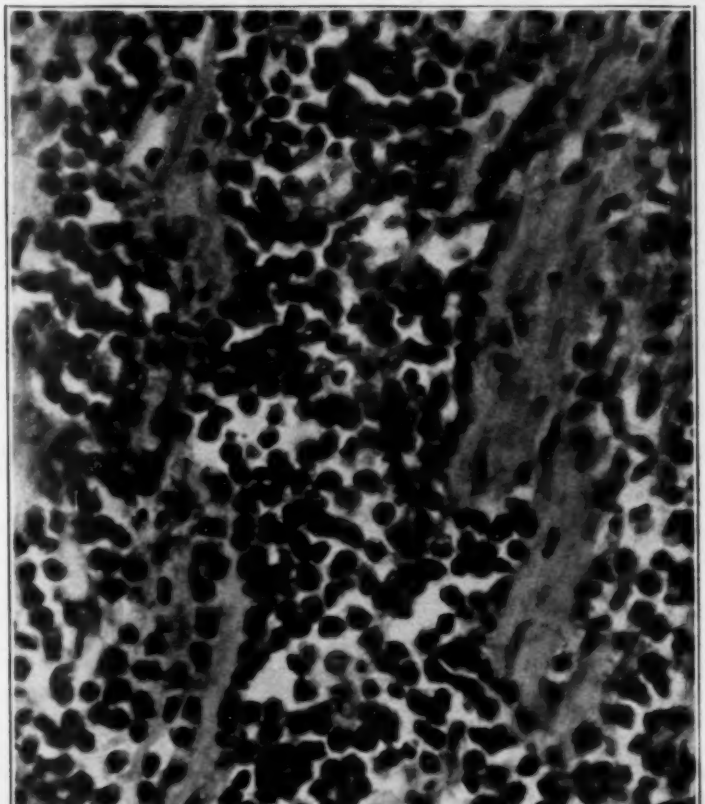

Fig. 5 (case 2).—Photomicrograph illustrating the uniform character of the cells as well as the invasion into the tissues.

of the ileocecal valve. The lumen at this point was narrowed but open. The growth was juxtaposed to the orifice and protruded into the lumen of the cecum, measuring 5 by 4 by 3.5 cm. in its various dimensions. The ileocecal valve was edematous. The mass was seen to lie in the distal portion of the ileum proximal to the valve. The mucous membrane was superficially slightly ulcerated. This area appeared to be an infarction in the tumor. At the angle formed by the ileum and the cecum there was a nest of enlarged firm, hard lymph nodes. On section of the tumor mass as well as of the lymph nodes there was observed a

uniform yellow-gray glistening white structure. The entire wall of the ileum at the site of the tumor appeared greatly thickened. The appendix was grossly unchanged (fig. 4).

Microscopic examination revealed an extremely cellular growth with numerous closely packed medium-sized lymphocytes all similar in appearance. All of these seemed to be mature lymphocytes, and mitotic figures in them were present in moderate numbers (fig. 5). In the area described as containing the infarct there was extensive necrosis. The blood vessels contained fibrin thrombi. The mucous membrane extending over the tumor seemed to be of the type in the large bowel or the colon. The lymphocytes seemed to invade the muscular layers as well as the serosa and to lie in dilated lymphatic spaces. All of the lymph nodes on examination revealed similar structure. In some portions of the section the cells appeared to be largely of the lymphoblast type.

The pathologic diagnosis was primary lymphosarcoma of the ileocecal valve.

Three weeks after discharge from the hospital, the patient began to have roentgen treatments as follows: January 30 to February 15, 1,600 r to the anterior lower portion of the abdomen with the use of a 0.13510 mm. tin filter, a 0.25 mm. copper filter and a 2.5 mm. aluminum filter. On March 20 he began a second series of treatments which were administered during a period from that date to April 10, 1,400 r to the anterior lower portion of the abdomen, 400 r to the anterior upper portion of the abdomen and 400 r to the lower portion of the abdomen posteriorly.

The patient continued to be nauseated and vomited at least once a day. On reentry to the hospital on April 10, he appeared weak and emaciated. The colostomy opening was functioning well. No other noteworthy changes had occurred, but he became progressively worse and died three days later. There was secondary anemia (hemoglobin content 62 per cent). The white blood cell count was 11,800 with 85 per cent polymorphonuclears and 5 per cent lymphocytes.

The autopsy by one of us (D. G. M.) disclosed the following pertinent conditions: recurrent metastatic lymphosarcoma involving the peritoneum, the heart, the anterior mediastinum, the mesentery and the retroperitoneal organs and tissues (the kidneys, the pancreas, the right psoas muscle and the periadrenal tissues); pulmonary atelectasis; emaciation; anemia, and hydronephrosis.

ETIOLOGY

The cause of these tumors, as of all tumors, is not definitely known. Lymphosarcoma of the intestine is most commonly found in male patients. The age incidence shows that the majority of instances occur in the third, fourth and fifth decades. In a group of 7 cases reported by Cheever, 4 of the patients were men and 3 were women; the average age was 53.5 years, the youngest patient being 30 and the oldest 75. The average range of ages given by him was 45 to 56. Thus it may be seen that the majority of these tumors come in the early tumor age period, although they may be found at any age. Ulman quoted Zwalenberg as observing one that developed six weeks after abdominal injury. Petersen [13] in a series of 85 cases found 3 in which the relation of the tumor

13. Petersen, E.: Sarcomas in Small Intestine, Hospitalstid. **66**:782 and 797, 1923.

to injury seemed apparent. In a single instance reported by Schaaf,[14] a male high school student aged 15 years had epigastric distress following a contest in which he was an anchor man in a tug of war, during which he tied the rope around his waist, experiencing a constricting effect on his abdomen. Intussusception with a tumor was found in the ileum.

Primary inflammatory processes have been commented on as possibly causative. Libman found reference to tuberculosis in 1 instance, syphilis in another and protozoan infection in still another. Rankin [15] commented on the association in 2 instances of lymphosarcoma of the large intestine with chronic ulcerative colitis. Like other neoplasms, therefore, the exact initiating agent is unknown. Some focal overtaxation of lymphatic function seems apparent.

PATHOLOGY

The most common site of lymphosarcoma of the intestines is said to be the ileum. Of the growths of this type occurring in the large intestine, the largest number are found in the rectum. Krueger [16] reported 37 cases, in 16 of which the tumor was in the ileum and in an equal number in the rectum. Speese collected 42 cases with the growths distributed as follows: 15 in the duodenum, 18 in the jejunum, 2 in the jejunoileum and 14 in the ileum. Ulman found the ileum involved in 48 cases among 126 authentic cases of lymphosarcoma of the small and large intestines. The majority of the lymphosarcomas of the small intestine are not unusually large. The tumor reported by Benjamin and Christopher [17] measured 4 by 4.5 by 4 cm. Lymphosarcomas have a tendency to lobulate and to grow expansively in the wall of the bowel. We agree with Cheever, who pointed out that they probably begin in a nidus of lymphoid tissue, such as a follicle in the submucosa, and then spread characteristically by obliterating the wall of the bowel. It is agreed that these lymphosarcomas have a scanty and delicate reticulum, so that there is little tendency for them to contract and restrict the visceral lumen. The infiltrating lymphosarcomas do not, therefore, develop into massive pedunculated growths, as do carcinomas, with extension to the peritoneal or visceral cavities. Ulcerations, so characteristic of carcinoma, occur late. Metastases, either regional or general, may occur by the blood or lymph stream. The regional metastases may be so striking as to overshadow the primary tumor growth. Cheever expressed the opinion that

14. Schaaf, R., and Kraemer, M.: Lymphosarcoma of the Ileocecal Valve, Rev. Gastroenterol. **7**:248, 1940.

15. Rankin, F. W., and Chumley, C. L.: Lymphosarcoma of the Colon and Rectum, Minnesota Med. **12**:247, 1929.

16. Krueger, F.: Die primären Bindegewebsgeschwülste des Magendarmkanals, Inaug. Dissert., Berlin, C. Vogt, 1894.

17. Benjamin, E. L., and Christopher, F.: Primary Lymphosarcoma of the Small Intestine, Am. J. Clin. Path. **10**:408, 1940.

the primary invasion of lymph nodes is by direct permeation rather than by free-cell metastasis. In 1 of the instances reported here the extension was apparently only through the wall of the bowel, while in the other the lymph nodes were seemingly involved. It is significant that the course seemed much more rapid in the younger person (case 2) although the cell type (mature lymphocyte) was seemingly less malignant. While both of these tumors seemed to occur in the lower end of the ileum, 1 (case 2) seemed to have more definitely developed in the ileocecal fold.

SYMPTOMATOLOGY

The signs and the symptoms of lymphosarcoma of the small intestine are dependent on their location, duration and extent. In the 2 instances here reported, the symptoms were somewhat similar except for intensity. One patient (case 1) complained of some indefinite long-standing disturbance in the bowel, having had a history of nausea, vomiting and bilious attacks in childhood and later constipation requiring excessive use of cathartics. The other patient's (case 2) complaints were less definite, but constipation was noted. In both atypical symptoms of incomplete obstruction, with tenderness, pain, tympanites, nausea and vomiting, finally developed. In case 1 the clinical impression was that the condition was regional enteritis; in case 2, that it was intestinal obstruction.

Speese pointed out that the symptoms may be slight at the onset with later associated pain, loss of appetite, nausea, vomiting, irregularity of the bowels, distention of the abdomen and possible palpable tumor. He classified lymphosarcomas of the small intestine as follows: (1) latent tumors, discovered by autopsy; (2) tumors with general manifestations, distention of the abdomen or presence of a mass being first noted; (3) tumors the first symptoms of which are due to intussusception or other intestinal obstruction or to perforation; (4) tumors with manifestations resembling those of tuberculous peritonitis; (5) tumors of which jaundice is the first symptom; (6) tumors resembling ovarian cysts; (7) tumors simulating appendicitis.[18] Symptoms vary in duration from three weeks to seventeen months with an average of six and a half months.[11] The chief complaints are abdominal pain, vomiting, constipation and loss of weight. Bloody or tarry stool was found in only 1 case. In many instances the tumor can be felt. Roentgen examination generally reveals residuum in the loops of the ileum, rigidity of the ileocecal valve, a filling defect of the cecum and distention and obstruction of the small intestine. Visible peristalsis and vomiting after meals may occur when a lympho-

18. Booth, cited by Goldstein. Goldstein, H. I.: Primary Sarcoma of the Intestines, Am. J. Surg. **35**:240 and 323, 1921; Primary Sarcoma of Appendix: Lymphosarcoma of Appendix with Acute Intestinal Obstruction in a Young Woman, Am. J. M. Sc. **161**:870, 1921. Hagyard, C. E.: Lymphosarcoma of the Appendix and Caecum, Northwest Med. **24**:342, 1925.

sarcoma is located in the upper part of the small bowel (Benjamin and Christopher). As Libman pointed out, partial stenosis with dilatation is one of the common characteristics. Lymphosarcoma of the intestine is insidious in its development and much more difficult to recognize than carcinoma.

Early diagnosis with complete and radical removal offers the only hope in a case of lymphosarcoma of the intestine, with which at best the prognosis is usually grave.

SUMMARY

Two cases of primary lymphosarcoma of the lower end of the small intestine are presented.

In one the clinical diagnosis was regional ileitis; in the other, intestinal obstruction, cause unknown. One patient (case 1) is still well three years after operation; the other (case 2) died four months after operation with general metastases.

Lymphosarcoma of the small intestine is relatively uncommon, there being approximately 376 authentic instances. In our own experience there was 1 case among 38,076 surgical tissues and 11,446 autopsies.

Although the prognosis is poor, early recognition and complete surgical removal offer the best chance.

The infrequency of lymphosarcoma of the small intestine has the same basis as does that of other tumors in this location, namely, the anatomic and functional character of the small bowel.

University of Oregon Medical School.

STAB WOUND OF THE PULMONARY ARTERY WITH SUTURE AND RECOVERY

REPORT OF A CASE WITH A BRIEF REVIEW OF TRAUMATIC CARDIAC SURGERY

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DURHAM, N. C.

Although suture of stab wounds of the heart is a relatively recently developed surgical procedure, some 345 cases have been reported in the literature with recovery in approximately 60 per cent. Elkin [1] estimated this rate to be somewhat too high, because numerous isolated cases in which treatment is unsuccessful are never reported. He therefor places the recovery percentage at no greater than 50 per cent, even at the present time.

In a careful search of the literature one finds that not only are instances of stab wounds of the intrapericardial portion of the pulmonary artery rare but the mortality rate has been 100 per cent. It is of considerable interest, then, to report a case of stab wound of the pulmonary artery with operation and complete recovery.

Excellent reviews of the history of heart wounds have been presented by Elkin, Bigger,[2] Peck,[3] Pool,[4] Glasser and associates,[5] and reference to their articles is suggested for a complete survey. Let it suffice here to say that the injury has long been recognized but that even the great Billroth [6] wrote that any attempt to treat such a wound operatively was not only prostitution of surgery but also madness. Rehn [7] is credited with the first successful suture of the human heart in 1896.

As with most operative conditions there has been a gradual decrease in the mortality rate with added experience through the years.

From the Department of Surgery, Duke University School of Medicine.

1. Elkin, D. C.: The Diagnosis and Treatment of Cardiac Trauma, Ann. Surg. **114**:169, 1941.

2. Bigger, I. A.: Wounds of the Heart and Pericardium, South. M. J. **25**: 785, 1932.

3. Peck, C. H.: The Operative Treatment of Heart Wounds, Ann. Surg. **50**:101, 1909.

4. Pool, E. H.: The Treatment of Heart Wounds, Ann. Surg. **55**:485, 1912.

5. Glasser, S. T.; Mersheimer, W., and Shiner, I.: Bullet Wound of Left Cardiac Auricle with Suture and Recovery, Am. J. Surg. **53**:131, 1941.

6. Billroth, cited by Ricketts, B. M.: Surgery of the Heart and Lungs, New York, Grafton Press, 1904.

7. Rehn, L.: Ueber penitrierende Herzwunde und Herznaht, Arch. f. klin. Chir. **55**:315, 1897.

In 1909 Peck listed 160 cases to date in which treatment was by operation; the mortality rate was 63.13 per cent.

In 1912 Pool added 77 cases with a mortality rate of 49 per cent.

In 1923 Smith[8] collected 49 additional cases with a mortality rate of 36 per cent.

Bigger collected 70 cases in 1933 with a mortality rate of 30 per cent, and in 1941 Elkin published 38 cases of his own or of his staff with a mortality rate of 42 per cent. Elkin and Bigger[9] reported the only cases of injury to the pulmonary artery intrapericardially. Each had 1 case. In 1 case death ensued during an attempted aspiration to relieve cardiac tamponade, and in the other case the patient died two days postoperatively. No autopsy was obtained, but clinically the patient had overwhelming pneumonia.

The chief causes of postoperative death have been listed by Bigger as infection, pulmonary infarction and recurring cardiac tamponade. The last might occur from insufficient closure of the heart wound and has led many to advise pericardial drainage for a few days. Pool, Bigger and Elkin advised against this, however, as being a possible cause of cardiopericardial adhesions and of infection. Instead, all advised closure of the pericardium with widely spaced sutures and possibly a small drain down to the pericardium.

MECHANISM OF INJURY AND PATHOLOGIC FUNCTION

The most common cause of injury in all cases reported has been a stab with a knife or an ice pick. Gunshot wounds rank next but apparently usually cause almost instantaneous death. Occasional glass splinters and similar shattered fragments are introduced by mechanical accidents. The majority of wounds, however, are inflicted with either suicidal or homicidal intent.

As soon as injury to the heart occurs, bleeding into the pericardial sac takes place. Since this is an inelastic structure and since the wound of entrance into it usually is rapidly plugged by the overlying muscle, the tension within the sac rises. This restricts the muscular activity of the heart, and since the tension rapidly rises above the pressure within the vena cava, it prevents the filling of the right auricle. The cardiac intake is diminished; cardiac output falls, and cerebral anemia rapidly produces death. This is known as death from cardiac tamponade, as the actual loss of blood is usually inconsequential.

A priori, then, the symptoms of this injury, must be: (*a*) distention of the veins of the neck with a high venous pressure; (*b*) a diminishing

8. Smith, W. R.: Cardiorrhaphy in Acute Injuries, Ann. Surg. **78**:696, 1923.

9. Bigger, I. A.: The Diagnosis and Treatment of Heart Wounds with a Summary of Twenty-Five Cases, South. M. J. **33**:6, 1940.

blood pressure with a rapidly disappearing pulse pressure; (*c*) irregularity of the cardiac rate and rhythm, and (*d*) unconsciousness with either stupor or wild delirium.

DIAGNOSIS

It is evident from Elkin's, Bigger's and Shipley's [10] experiences that the number of cases of cardiac wounds diagnosed varies with the degree of suspicion and care in examination.

The history, if obtainable, is usually that of freedom from symptoms for a few minutes. My patient was brought to the hospital by a friend and walked with some support. Others have walked or run a city block or more. Exhaustion soon follows. The position of the chest injury and the direction of the blow or shot if known assists in the diagnosis.

The patient shows all the signs of shock. Venous pressure may be taken by inserting a needle directly into a neck vein. It is frequently above 200 to 300 mm. of water. The heart sounds are weak and muffled. Cardiac dulness is enlarged. Pulse pressure is low. Fluoroscopy shows a quiet heart. Electrocardiograms are of no value and are contraindicated because of the unnecessary delay involved in obtaining them. Hesse,[11] Borchardt [12] and others have advised exploration when the diagnosis is probable but not positive. Typical cardiac tamponade was present in only 11 of 21 cases of Hesse, and hemothorax may complicate the diagnosis.

TREATMENT

In 1868 Fischer [13] collected 452 cases of heart injury. In all of these treatment was nonoperative; 10 per cent recovered. During the past ten years the average percentage of recovery in the cases reported (about 80 in all) has been 64 to 71 per cent.

The answer, then, is obvious. Moreover, as Rehn pointed out in 1896, a heart wound which has healed without surgical intervention leaves a weak scar which may rupture or become the site of an aneurysm. In 1899 Loison [14] collected 9 such cases. On the other hand, Le Fort and Decoulx [15] examined 55 cases twenty years after original injury

10. Dr. A. M. Shipley presented his experience in a clinic on wounds of the heart at Duke University School of Medicine, Dec. 10, 1940.

11. Hesse, E.: Ein Fall von 26 jährigen Bauerresultat einer Herznaht nach Schussverletzung, Zentralbl. f. Chir. **62**:1874, 1935.

12. Borchardt, M.: Ueber Herzwunden und ihre Behandlung; Pfahlungsverletzung von Herz und Lunge, Samml. klin. Vortr., 1906 (Chir. nos. 113-114), pp. 297-350.

13. Fischer, G.: Die Wunden des Herzens und des Herzbeutels, Arch. f. klin. Chir. **9**:571, 1868.

14. Loison: Des blessures du pericarde et du coeur et de leur traitment, Rev. de chir. **19**:774, 1899.

15. Le Fort, R., and Decoulx, P.: Bullets in the Heart and Mediastinum: Late Results in Fifty-Five Cases After More Than Twenty Years, J. de chir. **52**:1, 1938.

and obtained electrocardiograms in 16. These were all normal. Elkin stated that in his 22 successful cases there have been no residual symptoms.

TECHNIC

Various incisions have been advised, the principal ones being median sternotomy,[16] intercostochondral thoracotomy,[17] quadrangular flap [18] and the transverse incision of Elkin. In my case a left parasternal incision with a lateral flap after the manner of Meyer [19] and Nystrom [20] for removal of pulmonary embolus was used. This proved to be ideal under the circumstances.

Elkin noted that it is easier to separate rib from pleura than cartilage from pleura and therefore advised cutting the rib laterally; then by elevating the rib cartilage, one can remove it at the sternal junction. Usually the internal mammary artery has to be divided and ligated.

When the pericardial sac is opened, a search is made for the wound. This is closed with either catgut or silk interrupted sutures, the finger being placed over the wound and not into it, since the heart muscle is extremely friable. Beck [21] advocated stabilization of the heart by traction sutures through the apex. Pericardial blood is removed by suction, and the cavity is irrigated with physiologic solution of sodium chloride. Closure of the pericardium should not be too tight, as accumulation of serum and blood may reproduce the cardiac tamponade. If heart action ceases, release of tension, gentle massage and direct introduction of epinephrine will usually restore contraction.

The blood aspirated from the pericardial cavity may be citrated and reintroduced into the blood stream as an autotransfusion. Blood or plasma from a blood bank will be found helpful immediately postoperatively.

Local anesthesia is thought by some to be sufficient. Occasionally a patient has been so unconscious as not to require any anesthesia at all. Many patients are intoxicated or wildly delirious, and general anesthesia is necessary to control them. Elkin expressed a preference for positive pressure inhalation anesthesia, which permits control of

16. Duval, P., and Baudet, R.: Sur une observations de plaie penetrante du ventricule droit traitee par la suture, Bull. et mém. Soc. d. chirurgiens de Paris **33**:15, 1907.

17. Spangaro, S.: Sulli tecnica da seguire negli interventi chirurgici par ferite del curore e su di un nuovo processo di toracotomia, Clin. chir. **14**:227, 1906.

18. Fontan, J.: Plaie du coeur; suture du ventricule gauche; guérison, Bull. et mém. Soc. d. chirurgiens de Paris **27**:1099, 1901.

19. Meyer, A. W.: A New Technic for Successful Surgical Treatment of Pulmonary Embolism, Deutsche Ztschr. f. Chir. **231**:586, 1931.

20. Nystrom, G.: Experiences with the Trendelenburg Operation for Pulmonary Embolism, Ann. Surg. **92**:498, 1930.

21. Beck, C. S.: Wounds of the Heart, Arch. Surg. **13**:205 (Aug.) 1926.

accidental opening of the pleura. Bigger preferred local anesthesia, while Vakhamreev [22] used ether entirely. Since my patient was intoxicated, it was feared he would be difficult to control after release of the tamponade. Ether was the only general anesthetic available at the time of his injury and was therefore used.

POSTOPERATIVE COMPLICATIONS

Infection is the most common cause of postoperative death, with pneumonia and recurrent cardiac tamponade following. For this reason, although haste is usually necessary, scrupulous sterilization of skin and instruments and customary aseptic technic are imperative. An oxygen tent is of assistance postoperatively. Heparinization might be advisable to prevent intra-auricular and intraventricular clots with resultant embolus and infarcts. Thorough debridement or excision of the original wound tract should be carried out. Tetanus antitoxin or toxoid should be administered.

Occasional deaths have been due to tension pneumothorax. Careful frequent examination of the chest is essential to detect this as well as incipient pneumonia and empyema.

REPORT OF CASE

J. B., a 42 year old Negro man, was admitted to Lincoln Hospital on Oct. 13, 1940, about twenty minutes after having been stabbed in the left side of the chest anteriorly with an ice pick. Respirations were grunting. The patient denied any severe pain but complained of soreness and pressure within his chest.

Examination showed temperature 97.4 F., pulse rate irregular (counted by one nurse as 10 per minute, but 55 when I saw the patient a few minues later) and respiration rate 8. Blood pressure was 80 systolic and 62 diastolic. Immediate fluoroscopy showed a large boot-shaped practically pulseless heart shadow. The general physical examination revealed no abnormalities except a small puncture wound in the third interspace just to the left of the sternum which was not bleeding. During the time interval necessary to communicate with the service physician, Dr. J. W. V. Cordice (who gave me the opportunity of operating on this patient), and to set up the operating room, his blood pressure fell to 70 systolic and 58 diastolic and then to 60 systolic and 54 diastolic; the pulse pressure was only 6 mm. of mercury. The pulse rate remained around 60. He was cold with a clammy skin and was perspiring freely. Temperature forty-five minutes after admission and just before operation was 94.6 F. He was given 0.5 cc. of coramine (a 25 per cent solution of pyridine betacarboxylic acid diethylamide) immediately before anesthesia, and the blood pressure rose to 80 systolic and 66 diastolic.

With the patient under anesthesia induced with ether, an incision about 8 cm. long was made parallel to the left side of the sternum from the third rib to the fifth. This was converted to a T incision by adding a short lateral incision in the third interspace. The muscle was cut through and the rib exposed. The

22. Vakhamreev, P. I.: Heart Injuries Observed in Seven Cases, Vestnik khir. **52**:182, 1937.

cartilaginous portions of the fourth and fifth ribs were removed. (I believe that it would have been better to have removed the third instead of the fifth, as I had some difficulty in exposing the upper portion of the operative site.) The path of the stab wound could easily be followed by the amount of hemorrhage in the muscle surrounding it. After the cartilaginous portions of the ribs were removed, the internal mammary vein was slightly injured and had to be ligated, but the artery was not disturbed. There were a partial pneumothorax and a small hole in the pleura which was closed with a ligature. The pleura was then pushed laterally and upward; this exposed the pericardial sac which was tense and bluish. A small opening was made into the pericardium, and immediately there spurted upward a stream of dark blood. This was aspirated, and a total of about 400 cc. was removed. The heart action immediately improved both visibly and from the standpoint of the anesthetist, who reported the pulse as full and bounding. Inspection of the right auricle and the right ventricle showed no wound whatsoever. However, there was a small opening in the pulmonary artery, apparently about 1 cm. above the valves, from which, at each heartbeat, a stream of blood poured forth. With considerable difficulty, owing to the constant tearing of the sutures in this thin wall, the opening was closed. A purse string suture of double medium black silk was first used, and this was reenforced with several mattress sutures. The opening was about 4 to 5 mm. in diameter. The pericardium was then resutured with interrupted medium black silk sutures. The muscle was reapproximated with the same material, and the skin was closed with a layer of subcutaneous and a layer of superficial interrupted fine black silk. The patient returned to the ward in fair condition, his blood pressure being 90 systolic and 60 diastolic.

Postoperative Course.—The patient was given morphine sulfate and a continuous infusion of physiologic solution of sodium chloride immediately after the operation. Twelve hours later his blood pressure was 90 systolic and 60 diastolic and twenty-four hours after operation 100 systolic and 52 diastolic, and he felt fine. There were a few rales heard over the left lung field and some hyperresonance. It was felt that the pneumothorax had not entirely cleared up. On the following day fulminating bilateral bronchopneumonia with slight hemopneumothorax developed on the left. He was given blood transfusion and sulfathiazole (2-[paraaminobenzene-sulfonamido]-thiazole) in the usual doses. The response was excellent; the pneumonia subsided, and for a week he was afebrile. Then a daily elevation of temperature began again, and empyema was found to have developed on the left side. Trocar thoracotomy was performed with closed tidal drainage on November 11. The empyema finally cleared up, and the tube was removed on December 4. During part of this course there was mild infection of the chest wound, but this also healed. The patient was discharged from the hospital on December 10, sixty days after admission, with complete healing of both incisions and reexpansion of the lung, a normal heart shadow and some thickening of the pleura at the left base. Reexamination one year later showed him to be completely well at that time.

COMMENT

Venous pressure determination was not performed on this patient, as the physical signs and fluoroscopic examination pointed definitely to an intrapericardial wound. The most significant factor in establishing such a diagnosis was the rapidly diminishing pulse pressure, which was striking.

The pulmonary complications were not unexpected since the patient had partial pneumothorax with some hemothorax following penetration with a dirty weapon. In addition there was the trauma of a forty minute anesthesia induced with ether in a moderately intoxicated patient.

No transfusion or intravenous fluids were administered to this patient for forty-eight hours postoperatively so as not to augment any bleeding tendency by a rapid rise in blood pressure or cardiac output.

SUMMARY

A case of successful suture of a stab wound of the pulmonary artery is recorded. A short general discussion of the diagnosis and the treatment of perforating wounds of the heart is presented.

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ARTERIAL BLOOD FLOW IN EXTREMITIES WITH VARICOSE VEINS

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CINCINNATI

In view of the frequent association of varicose veins of the extremities with trophic changes in the skin, it becomes important to ascertain the state of the circulation in the former condition. Using the same patient, de Takáts and his associates [1] compared the gaseous content of venous blood from a normal upper extremity with that from a lower extremity with varicose veins and found a uniform increase in carbon dioxide and a decrease in oxygen content in the sample obtained from the lower limb. A similar procedure in a group of normal subjects revealed no such difference, at least as far as carbon dioxide content was concerned. On the basis of these results, the authors concluded that the tissues of a leg with varicosities are in a state of chronic anoxemia. According to them, this factor together with the retention of carbon dioxide and other waste products is responsible for the various cutaneous complications frequently seen with this condition. Using the histamine flare test, these authors obtained results which they interpreted as indicating that patients with varicosities also have some interference with arterial blood flow, possibly as a result of arteriolar spasm.

Blalock,[2] on the other hand, noted that in patients with varicose veins of one of the lower extremities the oxygen content from the femoral or saphenous vein was higher on the diseased side. This difference between the normal and the abnormal extremity was more pronounced when ulceration was present. No definite relation appeared to exist, however, with respect to the oxygen content of blood from the dilated veins in the lower part of the leg and that of blood from similarly located vessels on the control, normal side. According to him,

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From the May Institute for Medical Research, the Jewish Hospital.
This study was aided by a grant from the Samuel and Regina Kuhn Fund.

1. de Takáts, G.; Quint, H.; Tillotson, B. I., and Crittenden, P. J.: The Impairment of Circulation in the Varicose Extremity, Arch. Surg. **18**:671 (Feb.) 1929.

2. Blalock, A.: Oxygen Content of Blood in Patients with Varicose Veins, Arch. Surg. **19**:898 (Nov.) 1929.

the data suggested that the total flow of blood through a leg with varicose veins was increased. Holling and associates [3] confirmed Blalock's results in part by finding that the oxygen tension in the blood from the varicose saphenous vein was no lower than in that from the normal side.

Inasmuch as the procedure used in the investigations just cited serves only as an indirect measure of the rate of blood flow and since the results obtained by the different workers were for the most part contradictory, it was considered advisable to reinvestigate the subject by means of the venous occlusion plethysmographic method.

METHOD

The study was performed on a series of 13 subjects with varicosities of the lower extremities and 1 with sclerotic veins of the upper extremity; readings of blood flow in cubic centimeters per minute per hundred cubic centimeters of limb volume were obtained according to the technic previously described.[4] Patients with ulcers of the skin were not utilized (except 1 [M. C.]), since the venous occlusion plethysmographic method does not lend itself to the examination of open cutaneous lesions without the risk of aggravating the existing condition. In patients in whom the degree of involvement was practically the same in both lower extremities, only one lower extremity was studied; in other instances, in which the degree of involvement was different or in which only one side was affected, determinations were made on both legs simultaneously. In a number of patients the rate of flow in the normal forearm also was investigated. The temperature of the water in the plethysmograph was maintained at 32 C., and the temperature of the room varied between 25 and 27 C. After the subject had become accommodated to his environment, fifteen to twenty measurements of blood flow were obtained under resting conditions.

RESULTS

As controls for the results obtained in the present series of patients the readings of resting blood flow for a group of 84 persons previously reported [5] were utilized. Examination of the table reveals that in 11 of the extremities with varicose veins the rate of resting blood flow, in cubic centimeters per minute per hundred cubic centimeters of limb

3. Holling, H. E.; Beecher, H. K., and Linton, R. R.: Study of the Tendency to Edema Formation Associated with Incompetence of the Valves of the Communicating Veins of the Leg: Oxygen Tension of the Blood Contained in Varicose Veins, J. Clin. Investigation **17**:555 (Sept.) 1938.

4. Abramson, D. I.; Zazeela, H., and Marrus, J.: Plethysmographic Studies on Peripheral Blood Flow in Man: I. Criteria for Obtaining Accurate Plethysmographic Data, Am. Heart J. **17**:194 (Feb.) 1939. Ferris, E. B., Jr., and Abramson, D. I.: Description of a New Plethysmograph, ibid. **19**:233 (Feb.) 1940.

5. Abramson, D. I., and Fierst, S. M.: Resting Blood Flow and Peripheral Vascular Responses in Hypertensive Subjects, Am. Heart J. **23**:84 (Jan.) 1942.

volume, fell within the range for the normal group (1.4 [mean] with a standard deviation of 0.5), while in 5 the rate was somewhat increased beyond this range. In those patients in whom the degree of involvement was different in the two legs, no relation could be observed between the severity of the process and the rate of blood flow. Further, in subject D.S., in whom there was unilateral involvement, the values were the same for the normal limb and for the one with varicose veins. In the few instances in which readings for the forearm were obtained, the rate of blood flow fell within the range for the normal group, 1.8 ± 0.7 cc. per minute per hundred cubic centimeters of limb volume.

Resting Blood Flow in Legs with Varicosities

Subject	Age	Blood Flow, Cc. per Min. per 100 Cc. of Limb Volume		Degree of Involvement
		Normal Forearm	Involved Leg	
P. L.	41	...	1.2	4+
R. K.	51	...	1.5	4+
M. L.	41	1.4	2.3	2+
C. S.	35	...	1.1	4+
L. L.	..	...	1.7	2+
M. N.	49	...	1.3	2+
J. Z.	29	...	1.6 (right) 2.4 (left)	4+ 1+
S. C.	74	...	1.4	2 to 3+
D. S.	..	...	1.7 (left) 1.6 (right)	3+ Normal
S. L.	46	1.9	2.4	...
J. W.	63	...	1.8 (right) 1.3 (left)	3+ 2+
M. C.	67	...	2.0 (right) 1.1 (left)	3+ 1+
R. M.	60	1.5	2.4	3 to 4+

It is of interest that the 1 subject (not included in the table) who had markedly sclerotic veins of the upper extremity also had a normal rate of blood flow in the forearm (1.6 cc. per minute per hundred cubic centimeters of limb volume).

COMMENT

It is evident from these data that in our series of patients the circulation was not diminished in extremities with uncomplicated varicose veins. The findings, therefore, are not completely in accord with the view of de Takáts and his associates[1] that there is some interference with arterial blood flow in this condition, nor do they entirely support the opposite contention of Blalock,[2] who interpreted his data to indicate that an increased circulation is present.

As pointed out by a number of investigators,[6] the oxygen content of the blood in the large veins of the leg may not give a true representation of the oxygen content of the capillaries. It is possible that a shunting of blood directly from arterioles to venules may take place via the arteriovenous anastomoses, thus raising the total oxygen content of venous blood but at the same time actually diminishing the quantity available for tissue metabolism. This criticism, therefore, has been made in respect to determinations of blood flow based on the gaseous content of venous blood. However, it does not hold with regard to the venous occlusion plethysmographic method when applied to the leg, since an arterial occlusion pressure is maintained at the ankle during the period in which the circulation in the leg is being measured.[7] Inasmuch as the arteriovenous anastomoses in the lower extremity are for the most part limited to the foot, this procedure, which temporarily removes the distal portion of the extremity from the circulation, at the same time eliminates the variable factor of blood flow through these structures.

In view of our findings it does not seem reasonable to assume that the various cutaneous complications frequently present in an extremity with varicose veins result from a diminution of arterial circulation. The presence of venous and capillary stasis and the subsequent interference with the interchange of oxygen and waste products between the blood and the tissues[1] are probably a more likely explanation. Obviously, such a state would be conducive to an impaired nutrition of the tissues and hence a reduced resistance to infection. Further, the associated lymphatic obstruction also must be considered as playing an important role in the causation of the lesions.[8]

It must be reemphasized at this point that in most of the patients used in the present study cutaneous lesions were minimal or absent. Hence, the objection may be raised that data obtained on such subjects cannot be applied to the elucidation of the problem of these cutaneous complications. However, we still feel justified in stating that the varicosities by themselves do not contribute to the formation of ulcers insofar as any effect that they may have on the rate of arterial blood flow is concerned.

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6. Harpuder, K.; Stein, I. D., and Byer, J.: The Role of the Arteriovenous Anastomosis in Peripheral Vascular Disease, Am. Heart J. **20**:539 (Nov.) 1940. Holling, Beecher and Linton.[8]

7. Grant, R. T., and Pearson, R. S. B.: The Blood Circulation in the Human Limb: Observations on the Differences Between the Proximal and Distal Parts and Remarks on the Regulation of Body Temperature, Clin. Sc. **3**:119 (April) 1938.

8. Trout, H. H.: Ulcers Due to Varicose Veins and Lymphatic Blockage; New Principle in Treatment, Arch. Surg. **18**:2281 (June) 1929.

SUMMARY AND CONCLUSIONS

The peripheral circulation has been investigated in a series of 14 patients with varicose extremities by means of the venous occlusion plethysmographic method.

The rate of blood flow in the involved limb was found to fall within the range of that for normal subjects or somewhat beyond it. In no instance was decreased peripheral circulation observed in the extremity with varicose veins.

It is suggested that the various cutaneous lesions associated with varicosities do not have their origin in a diminished arterial inflow.

Mrs. William Littleford gave valuable technical assistance.

Jewish Hospital.

PROGRESS IN ORTHOPEDIC SURGERY FOR 1941

A REVIEW PREPARED BY AN EDITORIAL BOARD OF THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

(Continued from Page 862)

XII. CONDITIONS INVOLVING THE LOWER PART OF THE BACK

General Considerations.—A review of the literature of 1941 relating to conditions involving the lower part of the back reveals a sustained interest in lesions of the intervertebral disks and their relation to sciatica and pain in the lower part of the back. The clinical diagnosis is stressed by a larger number of writers, and a trend toward less frequent use of contrast mediums is reflected. Atypical cases of herniated disks call for visualization. Operative procedures are less radical in extent. The relation of fusion operation and disk removals is debated at length, although a trend to a combined operation is sensed in many of the articles. Spondylolisthesis and lumbosacral anomalies drop far behind disk lesions as subjects discussed in the writings of the past year.

The question of contracted fasciae is either a closed book or is receding in importance if the number of essays on the subject is a true reflection of the interest of orthopedic surgeons. The same may be said regarding manipulative and injection therapy for conditions involving the lower part of the back. Fibrositis has been passed by, attracting the attention of but a small group of writers. These and even other pathologic entities are referred to chiefly in their relation to disks.

Intervertebral Disks.—Adson [493] gives a splendid review of the present knowledge of disks and a good anatomic consideration. He considers myelography with iodized poppyseed oil as most reliable but does not utilize this method extensively because of the dangers and the medicolegal significance. He advocates a trial of orthopedic management before resorting to operation. Hemilaminectomy is the usual approach. This is combined with spinal fusion if instability of the spine warrants it. Aird [494] advocates the use of a blood pressure cuff as a means of increasing the intracranial pressure to differentiate lesions of mechanical origin from others. A pressure of 40 mm. of mercury is maintained for ten minutes while the neurologic examination is repeated. Positive results were obtained in 41 of 45 cases with space-consuming lesions, and

493. Adson, A. W.: Rupture of Intervertebral Disks as Cause of Low Back Pain and Chronic Recurring Sciatica, Proc. Interst. Postgrad. M. A. North America (1939), 1940, pp. 142-147.

494. Aird, R. B.: Prolonged Jugular Compression: Diagnostic Test of Neurologic Value, Arch. Neurol. & Psychiat. **45**:633-648 (April) 1941.

negative results were had in 54 cases in which such lesions were thought to be absent. [Ed. Note: This is a useful test but is one to be applied with caution.] Barr and Mixter [495] try conservative treatment. In cases in which operation is required combined laminectomy and fusion give better results than laminectomy alone. Ninety-four cases in which the follow-up was for more than one year are reported. Of these there was freedom from sciatic pain in 77 per cent and only slight leg pain in 18 per cent. The relief of pain in the back was less satisfactory. Seventy-three per cent of the patients on whom combined operation was done had no pain in the back, while but 52 per cent of those on whom laminectomy was done were free of back symptoms. Cacchi [496] calls attention to a narrowing of the neural canal in hypertrophy of the ligamentum flavum as contrasted to the defect seen in the posterior protrusion of the disk. Healing is favored by the use of diathermy or infra-red rays and a diet rich in vitamins. [Ed. Note: This is certainly only a possibility.] Craig and Walsh [497] state that the mobility of the nerve roots forming the cauda equina frequently allows abnormal pressure to cause pain without motor changes. Compression of a nerve root causes radicular pain, usually sharp, increased by coughing or sneezing and accompanied by local tenderness over the spine and by motor and sensory signs. Because of the sensory overlap section of a single root does not produce anesthesia. Lesions of nerve roots at the intervertebral foramens resulting from fracture, hypertrophic arthritis and spondylolisthesis must be kept in mind. Davis [498] finds the most common cause of pain radiating to the sciatic areas to be due to tumors of the cauda equina or arachnoiditis. De Morsier [499] states that urinary disturbances and sexual impotence are frequently associated with herniated disks. He found an inverse Lasègue sign in 2 cases. [Ed. Note: Is an inverse Lasègue sign a negative one?] Esser [500] reports 3 cases of herniated disks.

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495. Barr, J. S., and Mixter, W. J.: Sciatic Pain in Low Back Derangements: Its Incidence, Significance and Treatment; Symposium; Posterior Protrusion of Lumbar Intervertebral Discs, J. Bone & Joint Surg. **23**:444-456 (April) 1941.

496. Cacchi, R.: Hernia of the Intervertebral Discs, Especially of Lumbar Segment: Surgical Therapy, Gior. di clin. med. **21**:1223-1249 (Dec. 30) 1940.

497. Craig, W. M., and Walsh, M. N.: Neuro-Anatomic and Physiologic Aspects and Significance of Sciatica, J. Bone & Joint Surg. **23**:417-434 (April) 1941.

498. Davis, L.: Neurosurgical Lesions: Diagnosis and Treatment of Those Producing Pain in Back, Indust. Med. **10**:55-58 (Feb.) 1941.

499. de Morsier, G.: Frequent Cause of Lumbago and Sciatica: Traumatic Dislocation of Lumbar Intervertebral Disks with Posterior Nuclear Hernia, Rev. méd. de la Suisse Rom. **60**:999-1011 (Nov. 25) 1940.

500. Esser, P. H.: Prolapse of Intervertebral Disks, Geneesk. gids **18**:748-753 (Aug. 30) 1940.

Heine [501] states that Luschka described prolapse of the intervertebral disk more than eighty years ago. Naffziger [502] finds minor bladder difficulties common in disk cases. Atrophy of the leg on the involved side is common. Jugular compression pain develops in 60 per cent of the cases. Air myelography is tried first, but if the result is debatable, 3 cc. of iodized poppyseed oil is used. Bradford [503] reports histologic studies of 20 herniations. Nucleus pulposus was found in all cases; the inner layers of the annulus fibrosus were found in 16 cases, and the outer layers, in none. He estimates that a total force of more than 1,600 pounds (725.75 Kg.) may be put on the lumbosacral disk when a man lifts a 100 pound weight (45.4 Kg.) with arms outstretched. Dandy [504] states that the great majority of injured intervertebral disks can be diagnosed and localized to the fourth or fifth lumbar interspaces by obtaining the history and making clinical examination alone and that exploration of these areas by a unilateral approach should be carried out without subjecting the patient to an accessory diagnostic test of myelography or even of simple lumbar puncture. The diagnosis is not always unequivocal, but the percentage of error should be small. During the eight months preceding the time of writing the author removed disks from 29 patients who had received no spinal injection.

In 10 cases Dandy found concealed disks with a protrusion too small to be shown by myelography. These disks are bound to the emerging spinal nerve by adhesions and are softer to touch than the normal disk. When the covering ligament is incised, forceps sink deeply into the intervertebral space with little pressure, and a mushy brownish material may be removed with a curet. Results of opening of the flat disks have not been so good as in large protrusions, probably because the incision allows gradual escape of the injured disk material. The existence of these concealed disks is another argument against myelography. Dandy has had no recurrences (of pain low in the back or sciatic pain?) and has never felt fusion to be advisable following the disk operation.

The use of myelography in the diagnosis of herniated disks is going through a transition. Various mediums are employed, notably air, oxygen, colloidal suspension of thorium dioxide, iodized poppyseed oil

501. Heine, J.: Anterior Protrusion of Intervertebral Discs, Chirurg **12**:611-614 (Oct. 15) 1940.

502. Naffziger, H. C.: Diagnosis of Protrusions from Intervertebral Disks, Proc. Interst. Postgrad. M. A. North America (1940), 1941, pp. 122-125.

503. Bradford, F. K.: Certain Anatomic and Physiologic Aspects of Intervertebral Disc, South. Surgeon **10**:623-629 (Sept.) 1941.

504. Dandy, W. E.: Concealed Ruptured Intervertebral Disks: Plea for Elimination of Contrast Mediums in Diagnosis, J. A. M. A. **117**:821-823 (Sept. 6) 1941.

and other contrast substances. Some writers reserve myelography for the questionable cases, feeling confident that the clinical picture is diagnostic in 90 per cent of the cases. Other surgeons fear the pathologic and medicolegal complications which may arise from contrast mediums which cannot be completely removed. From the histologic point of view Benedek and Juba [505] describe an oleogranuloma found at autopsy following the injection of iodized poppyseed oil. Headley-Blythe and Anderson [506] warn of degenerative changes which follow the nonremoval of iodized poppyseed oil. In 2 cases secondary operations to relieve pain were necessary, and in 1 case necrosis of the cord was revealed at autopsy, possibly the result of contrast myelography. Kubik and Hampton [507] have removed the iodized poppyseed oil shortly after fluoroscopic examination in 30 cases by section. A delay in removal permits the oil to penetrate along the nerve sheaths. Lyerly [508] uses oxygen in the diagnosis of obscure lesions. Marcovich, Walker and Jessico [509] report on 150 patients who received from 2 to 4 cc. of iodized poppyseed oil. Forty-six and four tenths per cent had no immediate symptoms. Twenty-three patients had slight fever; pain was aggravated in 9; nausea occurred in 2; vomiting, in 2, and stiff neck, in 1. The spinal fluid cell count and total protein were elevated for at least several days following injection. The authors believe that opening of the dura contributes to rapid encystment of the oil. Nichols [510] does not feel that air myelography is reliable and has used 5 to 10 cc. of colloidal suspension of thorium dioxide. From 70 to 90 per cent is removed by immediate forced drainage. [ED. NOTE: Films obtained by this method are clear and reveal much more detail than those resulting from the use of the more contrasty iodized poppyseed oil.] Scott and Young [511] advocate air myelography with films taken during extension and flexion. They

505. Benedek, L., and Juba, A.: "Late Block" During Myelography with Lipiodol (Iodized Oil), Deutsche Ztschr. f. Nervenh. **151**:55-62, 1940.

506. Headley-Blythe, J., and Anderson, C.: Lipiodomania, M. Press **205**: 122-123 (Feb. 5) 1941.

507. Kubik, C. S., and Hampton, A. O.: Removal of Iodized Oil by Lumbar Puncture, New England J. Med. **224**:455-457 (March 13) 1941.

508. Lyerly, J. G.: Herniation of Intervertebral Disk, J. Florida M. A. **27**:491-500 (April) 1941.

509. Marcovich, A. W.; Walker, A. E., and Jessico, C. M.: Immediate and Late Effects of Intrathecal Injection of Iodized Oil, J. A. M. A. **116**:2247-2254 (May 17) 1941.

510. Nichols, B. H.: Symptoms and Diagnosis of Herniated Nucleus Pulposus, Proc. Interst. Postgrad. M. A. North America (1940), 1941, pp. 367-369.

511. Scott, M., and Young, B. R.: Sciatic and Low Back Pain: Diagnostic Value of Air Myelogram, J. M. Soc. New Jersey **38**:24-26 (Jan.) 1941.

explain remissions of sciatica as resulting from the mobile disks. [ED. NOTE: The long remissions must be due to other factors; otherwise the episodes would be of short duration and would recur several times daily in active persons.] Weber [512] injects 60 to 80 cc. of air into the epidural space via the sacral hiatus. The results were not satisfactory in a limited number of cases. Echols [513] discards total protein determinations and reserves myelography for atypical cases.

Sciatica.—Auersperg [514] classifies sciatica as intervertebral (radicular sciatica), intrapelvic (funicular sciatica), extrapelvic (peripheral sciatica) and symptomatic. In the last named, the reaction is direct from continuous destructive processes; in essential sciatica it is indirect from a distance. Bauer and Hellsten [515] infiltrate the lumbar sympathetic chain of the affected side for rapid relief of idiopathic sciatica. Blewett [516] demonstrates the narrowing of the lumbosacral disk space and anterior slipping of the fifth lumbar vertebra in the upright position in 2 cases of sciatica complicating spondylolisthesis [ED. NOTE: Comparison of roentgenograms taken with the patient in the supine and in the upright position is most valuable in diagnosing such lesions.] Brocker [517] is inclined toward the theory of the vertical origin of sciatica inasmuch as he rarely finds inflammatory lesions of the nerve at this level, whereas sacrolumbar degenerative articular changes are common. Bumm [518] believes sciatica is frequently due to a synergy of various causes. Thus the initial lesion may be that of compression followed by infection. He feels that in 90 per cent of the cases sciatic pain is due to arthritis of the interapophysial articulations as emphasized by Putti. Scoliosis is often associated with sciatic pain and in many instances is the cause rather than the result of the sciatic symptoms. [ED. NOTE: The relation of synovitis of the lateral articulations at the lumbosacral level to sciatica is often overlooked. It is reasonable to assume that inflammatory synovial reactions adjacent to the roots of the lumbosacral plexus may be referred to the sciatic nerve.]

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512. Weber, H. M.: Epidural Air Injection in Diagnosis of Spinal Canal Masses, California & West. Med. **54**:27 (Jan.) 1941.

513. Echols, D. H.: Neurosurgical Treatment of Sciatic Pain with Notes on Fifty Consecutive Cases, New Orleans M. & S. J. **94**:265-270 (Dec.) 1941.

514. Auersperg, A.: Symptomatologic Aspects of Sciatica, Wien. klin. Wchnschr. **53**:951-953 (Nov. 15) 1940.

515. Bauer, G., and Hellsten, W.: Procaine Hydrochloride Block of Lumbar Sympathetic as Adjuvant Therapy in Lumbago-Ischialgia: Preliminary Report, Nord. med. (Hygiea) **9**:601-603 (Feb. 22) 1941.

516. Blewett, J.: Cases of Spondylolisthesis of Unusual Interest, Brit. J. Radiol. **13**:416-421 (Dec.) 1940.

517. Brocker, J. E. W.: Sciatica of Vertebral and Nervous Origin, Helvet. med. acta **7**:355-420 (Oct.) 1940.

518. Bumm, E.: Etiology and Pathogenesis of Sciatica, Med. Welt **14**:814-817 (Aug. 10) 1940.

Grunbaum [519] injects into the sciatic nerve large quantities of physiologic solution of sodium chloride and has had favorable results. When the sciatica is predominantly fibular in location, the injection is made 6 to 8 cm. from the head of the fibula. Cures in 70 per cent of the cases are reported. Guk,[520] using the technic of Vichneoski, has employed procaine hydrochloride block in 84 cases of sciatica. In 64 cases two blocks six days apart were sufficient; in the other cases one block sufficed. In 50 of Kellgren's [521] 70 cases ligamentous or muscular lesions were found; in 15 there were displaced intervertebral disks, and in 5 there were miscellaneous diseases. In no case could the pain be ascribed to interstitial neuritis of the sciatic disease. The author believes this entity rare or nonexistent. Livingston [522] locates a trigger point in the multifidus triangle in the lower sacral area. He has given 14 patients repeated injections with 5 to 10 cc. of 2 per cent solution of procaine hydrochloride. The results were good. Thurel [523] finds that in epidural injections of procaine hydrochloride for therapeutic purposes, the pain is always reawakened when the fluid comes in contact with the painful nerve. Ferrandu and Forni [524] experimenting with sterile bile injections into the sciatic nerve of rabbits found peripheral degenerative processes.

Odom and Kolczum [525] describe a type of nerve block which they have found to be effective, namely, epidural injection of procaine base in almond oil in cases of sciatica in which no mechanical lesion is demonstrable. With the patient sitting erect and the area anesthetized with 1 per cent procaine hydrochloride solution, a needle is introduced into the second lumbar interspace. Entrance into the spinal canal is determined by negative pressure as shown by a liquid in a glass tube attached to the needle. Twenty cubic centimeters of 2 per cent procaine base in almond oil is then injected. This treatment was used in 42 cases in which the duration of the sciatic pain ranged from

519. Grunbaum, R.: Treatment of Sciatica with Special Reference to Injection of Large Amount of Physiologic Salt Solution, Rev. neurol. de Buenos Aires **5**:147-150 (April-June) 1940.

520. Guk, V. T.: Procaine Hydrochloride Block in Therapy of Lumbago and Sciatica, Gaz. clin. **38**:331-332 (Sept.) 1940.

521. Kellgren, J. H.: Sciatica, Lancet **1**:561-564 (May 3) 1941.

522. Livingston, W. K.: Back Disabilities Due to Strain of Multifidus Muscle: Cases Treated by Injection of Novocain, West. J. Surg. **49**:259-265 (May) 1941.

523. Thurel, R.: A Constant Pathognomonic Sign of Sciatica with Renewal of Pain upon Epidural Injection, Rev. neurol. **72**:466, 1940.

524. Ferrandu, S., and Forni, G.: Peripheral Degenerative Neuritis Due to Application of Sterile Bile on Trunk of Sciatic Nerve of Rabbit, Ann. ital. di chir. **19**:675-679 (July-Aug.) 1940.

525. Odom, C. B., and Kolczum, M. C.: Treatment of Idiopathic Sciatica by Epidural Injection of Almond Oil and Procaine, South. M. J. **34**:1149-1151 (Nov.) 1941.

one month to seven years. Forty-one of these patients, or 97 per cent, secured immediate relief from the injection. Lasting relief over a period of twenty to thirty-six months was obtained in 38 cases, or over 90 per cent. The authors also gave injections of iodized poppyseed oil in 10 cases to show the diffusion of solution into the epidural space and found that in all cases the diffusion was more rapid on the affected side than on the unaffected side. The reason for this is not clear. The authors recommend that this treatment be employed for relief of pain before other more radical procedures are attempted.

Ober [526] and Pickett [527] stress the importance of physical therapy in cases of conditions involving the lower part of the back and employ some form of fasciotomy in cases in which the condition is resistant.

Pribek [528] upholds the value of skin temperature determinations in differentiating sciatica from lumbago. Badgley [529] has made an exhaustive study of a long series of cases of sciatica and concludes:

> The radiation of the pain in so-called sciatica is not nerve root irritation but is plexus in distribution. . . . There is a possibility that the radiation may be due to a referred mechanism from stimulation of peripheral pain fibers in the muscles, ligaments or articulations of the low back with central localization through overflow into the fibers from the postaxial surface of the leg.

The Lumbosacral Joint.—Spondylolisthesis has received little attention in the literature of 1941 and does not compete effectively with the disk wave which engulfs us for the present. Burckhardt [530] uses the term "spondylolisthesis imminens" to designate cases of spondylolysis. He believes the defect of the isthmus is of congenital origin and that symptoms may appear spontaneously or be released by trauma. He reports 63 cases. Nagura [531] attributes the spondylolisthesis to an original interruption of the continuity of bone at the isthmus with replacement by fracture-healing processes in the cartilage. Breck [532] emphasizes the greater incidence of lumbosacral lesions as compared with lesions of the

526. Ober, F. R.: Salvaging Lame Back Patient, Arch. Phys. Therapy **22**:583-586 (Oct.) 1941.

527. Pickett, J. C.: Role of Fascia in Low Back Pain, South. Surgeon **10**: 738-746 (Oct.) 1941.

528. Pribek, L.: Cerebrospinal Fluid Findings and Skin Temperature Measurements in Differential Diagnosis of Sciatica, Klin. Wchnschr. **20**:320-321 (March 29) 1941.

529. Badgley, C. E.: Some Significant Anatomical Facts of Importance in Study of Sciatica, Univ. Hosp. Bull. Ann Arbor **7**:95 (Nov.) 1941.

530. Burckhardt, E.: Spondylolisthesis, Schweiz. med. Wchnschr. **70**:1093-1101 (Nov. 16) 1940.

531. Nagura, S.: Spondylolisthesis in Light of Cartilaginous Callus Formation, Beitr. z. klin. Chir. **171**:346-353, 1940.

532. Breck, L. W.: Newer Aspects of Low Back Pain, Southwestern Med. **24**:401-404 (Dec.) 1940.

sacroiliac joint as the source of pain in the lower part of the back. The downward subluxation of the fifth lumbar vertebra on the sacrum associated with narrowing of the lumbosacral disk is important. The author outlines treatment as described by Williams to flex the lumbar spine reducing the lordosis. Harris [533] holds that the mechanical weakness, increased lumbosacral angle and narrowed disk as well as the posterior rotation of the pelvis are the chief factors causing pain in the lower part of the back. Wichtl [534] states that all intervertebral disks are subject to physiologic aging. This is especially true at the lumbosacral juncture (osteochondrosis). The clinical significance of this condition lies in the presence of sciatic symptoms probably related to the intervertebral articulations. The narrowed lumbosacral disk is attributed to physiologic growth and involution processes as has been observed in the disks of the sacrum. Sacralization of the last lumbar vertebra was studied by Gabetti.[535] In 855 pelves, 78 cases of sacralization were found, 49 bilateral and 29 unilateral.

Patients with painful symptoms received daily epidural injections of 10 cc. of a solution of 0.25 per cent cocaine, 0.5 per cent phenol and 0.75 per cent sodium chloride solution. Five patients were subjected to resection of the transverse processes with good results.

Discussions of the sacroiliac joint are conspicuous by their absence, but there are one or two articles of general scope. These reveal nothing new.

Causalgic Backache.—Hudson, Hettesheimer and Robin [536] describe causalgic backache. Unilateral pain in the upper lumbar region, aggravated by recumbency awakening the patient at night and accompanied by pain radiating along the twelfth rib and to the groin, is a definite symptom complex. The findings are downward tilt of the pelvis on the painful side, increased lordosis, postural scoliosis, abduction and internal rotation of the thigh on the affected side. Tenderness and hyperesthesia are present along the twelfth dorsal and first lumbar nerves. The mechanism is described as due to a spasm of the quadratus lumborum muscle resulting in compression or tension of the twelfth dorsal and first lumbar nerves. Thirty patients treated by elevating the heel on the low side are reported to have been relieved.

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533. Harris, H. W.: Low Back Pain, J. Med. **21**:469-471 (Jan.) 1941.

534. Wichtl, O.: Reduction in Width of Last Lumbar Disk and Occurrence of Lumbosacral Transitional Disks: Relation to Sacralization, Fortschr. a. d. Geb. d. Röntgenstrahlen **62**:229-247 (Oct.) 1940.

535. Gabetti, D. C.: Therapy of Painful Sacralization of Fifth Lumbar Vertebra, Arch. per le sc. med. **71**:105-156 (Feb.) 1941.

536. Hudson, O. C.; Hettesheimer, C. A., and Robin, P. A.: Causalgic Backache, Am. J. Surg. **52**:297-303 (May) 1941.

Ligamentum Flavum.—Mensor and Fender [537] discuss the ligamentum flavum from the anatomic point of view and its relation to pain in the lower part of the back. They present the results of studying ligamenta flava which were removed from 26 patients at operation, measured and examined microscopically. These specimens were taken regardless of whether they were suspected of causing backache. Specimens from cadavers in various age groups without known history of back trauma were also studied. The authors think that the size and the thickness of the ligamentum flavum alone are unimportant as possible causative factors in back pain and sciatica unless changed by trauma or disease or causing pressure symptoms in combination with skeletal or disk changes or both. They feel that measurements of the ligamentum flavum are of little value because of technical factors which prevent the establishment of any fixed standard and because the size and thickness have been shown to vary with age, anatomic and pathologic structural changes and location in the individual case. From their microscopic studies the authors conclude that the ligamentum flavum reacts to disease or trauma by a loss of the normal structure of its elastic fibers and the development of a substitution fibrosis with replacement by collagen elements. Definite degenerative factors occur in the ligamentum flavum with advancing age, giving pathologic changes similar to those seen in trauma and disease. The authors feel that hypertrophy is an unsuitable term as no increase in elastic elements with preservation of a normal histologic appearance has been observed. The authors have demonstrated a definite nerve supply chiefly nonmedullated in type to the ligamentum flavum.

XIII. CONDITIONS INVOLVING THE SPINE AND THORAX, EXCLUSIVE OF THOSE IN THE LOWER PART OF THE BACK

Causes of Scoliosis.—The causation of so-called idiopathic scoliosis still remains unknown, and the failure of general agreement among those working with cases of this condition is well shown by Shands, Barr, Colonna and Noall [538] in their study of the end results of treatment. In a survey of sixteen orthopedic clinics throughout the country an expression of ideas concerning the causation of the idiopathic type of scoliosis has been obtained from the workers in the clinics, and these views have been divided into five general groups as shown in the table hereinafter reproduced.

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537. Mensor, M. C., and Fender, F. A.: Ligamentum Flavum: Its Relationship to Low Back Pain, Surg., Gynec. & Obst. **73**:822-827 (Dec.) 1941.

538. End Result Study of Idiopathic Scoliosis: Report of Research Committee, J. Bone & Joint Surg. **23**:963-977 (Oct.) 1941.

[Ed. Note: It is interesting, however, to see that the majority of clinicians feel that there is at least some associated metabolic disturbance as a factor and that fewer workers believe that unrecognized poliomyelitis is the major cause of idiopathic scoliosis. It is worthy of note that apparently six of the clinicians still hold to the old belief that "prolonged sitting in school" is an important factor. Most investigators who have been studying the problem of scoliosis during the past few years do not feel that the idiopathic type is appreciably influenced by postural faults, especially those associated with prolonged sitting in school. It is more generally felt that it is a condition of unrecognized causation

Etiology

Probable Etiology of Idiopathic Scoliosis	Clinicians Supporting View
Curvature is the result of failure of muscular and skeletal systems to maintain a balance during the rapid growth period, and is associated in some way with an endocrine or metabolic disturbance	4
Curvature is primarily the result of muscle imbalance, the source of the imbalance being unexplained, but possibly being postural fatigue, and unrecognized poliomyelitis, or some similar process	7
Curvature is the result of a growth disturbance at the epiphyseal plate of the vertebrae, possibly related to an osteochondritic process or to epiphyseal trauma with an associated deficiency, either metabolic or dietary	6
Curvature is the result of postural faults, acquired during growth and fatigue of adolescence, prolonged sitting in school, etc., which gradually lead to a fixed deformity	6
Curvature is an exaggeration of physiologic deviation occurring during normal gait, being greater toward the right side due to the weight of organs, and passing beyond normal limits in the presence of some body insufficiency	2
Hereditary and environmental factors are felt to be definitely contributory	2

occurring during adolescence and usually self limited as to progress, although the end result of the deformity may be slight or severe.]

Farkas [539] reports a study of physiologic scoliosis. He points out that Sabatier found that the great majority of adult spines show a well defined curve to the side and that in the lumbar and cervicothoracic segments the convexity is usually to the left side and in the thoracic region to the right side. Farkas has studied 20 complete normal skeletons, ranging from 19 to 86 years of age. He has confined his studies to the vertebrae alone and concludes that the postnatal regular asymmetric development of the human spine is due to some powerful automatic function which becomes established just prior to the age of 6 years. He states that physiologic scoliosis is a postnatal development,

539. Farkas, A.: Physiological Scoliosis, J. Bone & Joint Surg. **23**:607-627 (July) 1941.

that it is not due to the regular variation of the normal or to the innate formative energy of the cells or to the proximity of another organ, such as the descending aorta, but that it is caused by a function continuously at work. Farkas also states that in 100 spines reviewed none were without a more or less marked lateral curve, although no 2 spines were found with identical lateral curves. He believes that the human gait is the cause of physiologic scoliosis. [ED. NOTE: This is an interesting study and brings up many questions about the possible causation of so-called idiopathic scoliosis. However, this physiologic scoliosis must not be confused with pathologic scoliosis, and it remains to be shown whether these conclusions regarding physiologic scoliosis have any significant bearing on the production of idiopathic scoliosis.]

Wenger and Herman [540] have studied the roentgen films of 256 cases of scoliosis following thoracoplasty operations at Sea View Hospital, Staten Island, N. Y. They believe that it is not necessary to resect the transverse processes for adequate cavity closure and suggest that the operation be modified to leave the transverse processes unharmed. They conclude that the removal of the transverse processes is the main cause of scoliosis following thoracoplasty. They also suggest that to insure against spinal deviation in cases in which the dorsal intrinsic musculature is unsatisfactorily or inadequately developed the periosteum of the ribs should be immobilized to the tips of the transverse process below its own level so that when regeneration of bone does occur it will act as an internal splint.

[ED. NOTE: It has been previously suggested that the scoliosis following thoracoplasty is the result of the disturbance of the muscle and bone balance. While it is obviously true that the muscular attachments to the transverse processes are a definite factor, the ribs and their muscular attachments have undoubtedly an important mechanical bearing on the production of scoliosis in these cases. It seems that further study is necessary to establish the importance of the transverse processes as the major factor in post-thoracoplasty scoliosis. In 1 of the cases presented six ribs were resected on one side and seven on the other at the same level, but scoliosis did not develop. The authors conclude that this was because the transverse processes were not disturbed. However, one would expect no curve to develop in such a case; if an equal disturbance of bone-muscle balance resulted on each side, it would not matter whether ribs or transverse processes were removed. It should be noted also that in many of these cases it is difficult to determine accurately from roentgen study actually how much, if any, of the transverse processes has been destroyed. The authors may be correct in

540. Wenger, H. L., and Herman, M.: Role of Transverse Process in Thoracogenic Scoliosis, Quart. Bull., Sea View Hosp. **7**:45-55 (Oct.) 1941.

stating that it is not necessary to remove the transverse process in order to get adequate collapse of the chest after thoracoplasty. The removal of the transverse process may be a factor in making the curve greater, since there is greater destruction of muscle attachment and bony leverage. However, it seems likely that the major problem in the production of post-thoracoplasty scoliosis is the disturbance of the bone-muscle balance due to the removal of the ribs and their muscular attachments rather than to the removal of the transverse processes alone.]

Paralytic Scoliosis.—Colonna and vom Saal [541] report a study of 500 cases of poliomyelitis and review the findings in a series of 150 patients with paralytic scoliosis. They analyze some of the mechanical factors involved in the development and the treatment of the lesions. They attempt to determine the reason for the development of the curvature and its possible prevention and treatment. They report that 62 per cent of all their cases of scoliosis were due to poliomyelitis. [ED. NOTE: This is a much higher incidence of poliomyelitis scoliosis than that of other clinics and may have been due to the facts that the cases of poliomyelitis were more severe and that the patients came for treatment of the scoliosis or other deformities while many patients with idiopathic scoliosis, which is often milder, might not have been sent to the clinic for study. In some clinics the incidence of poliomyelitis scoliosis is about 5 per cent, while the number of patients admitted for operation may represent 50 per cent because of the greater need for treatment and other factors.] The authors are impressed by the effect of the hip and shoulder muscles on the production of paralytic scoliosis and show illustrations of curvatures apparently due to contracture of muscles on the concave side and other curves due to contractures on the convex side. They report 28 cases of paralysis of the trapezius muscle and 42 cases of paralysis of the rhomboid muscles. Paralysis of the deltoid muscle gave rise to a curve toward the sound side in 23 of 45 cases. They also state that in addition to the pull of the asymmetric muscle forces, the uncomplicated inequality of the length of the legs is sometimes sufficient to initiate the process. Unequal length of the legs is felt to have been the primary factor in 22 cases in this series.

[ED. NOTE: It is difficult to agree with some of these conclusions. Since the shoulder girdle is hung from the trunk when at rest in the upright position, one would not expect to see structural scoliosis develop as a result of the paralysis of the shoulder muscles alone. Patients with paralysis of the deltoid and other shoulder muscles (e. g. those with

541. Colonna, P. C., and vom Saal, F.: Study of Paralytic Scoliosis Based on Five Hundred Cases of Poliomyelitis, J. Bone & Joint Surg. **23**:335-353 (April) 1941.

Erb's paralysis) usually have little if any scoliosis, and if they do have it, it is of the functional type. Also, patients with amputation of the shoulder and resulting muscle imbalance are usually able to hold the spine straight although postural scoliosis during activity may develop. It should also be pointed out that there are many trunk muscles the asymmetric involvement of which may be impossible to estimate. It is difficult or impossible in any case of paralytic scoliosis to tell absolutely what muscles are involved in the first place, and as has been pointed out by others previously, the permutations and the combinations of possible muscle paralysis make the accurate estimate of the resulting force impossible. It should also be pointed out that an uncomplicated short leg causes functional scoliosis, convex to the side of the short leg when the patient is standing, and that this scoliosis disappears when the patient sits erect if the pelvis is level. It is hard, therefore, to accept the statement that "unequal leg length was felt to be the primary factor in 22 cases in this series." The short leg may have added to the problem of scoliosis due to paralysis of some of the intrinsic muscles of the trunk which it may have been impossible to detect as asymmetrically involved. But if the short leg were an important factor in producing structural scoliosis in persons with poliomyelitis, then one would expect all persons with poliomyelitis with short legs to have structural scoliosis. Functional scoliosis due to short leg represents an entirely different problem from the structural scoliosis following asymmetric paralysis of the muscles supporting the spine.]

Bisgard [542] again calls attention to the problem of chest and spine deformities, especially scoliosis, resulting from thoracic disease and operation. He divides thoracogenic scoliosis into two types: pleurogenic and thoracoplastogenic, the pleurogenic being due to

> . . . pleural scar resulting from chronic pleuritis from any cause, such as a simple serous tuberculous effusion or tuberculous or nontuberculous empyema . . . [which] contracts gradually and through adherence to the ribs pulls them centripetally.

[ED. NOTE: Although the author does not mention it, he probably includes the cases due to actual fusion of the ribs on the concave side of the curve following osteomyelitis of the ribs after rib resection and drainage under the same heading as those cases due to scar contracture caused by pleuritis. It should be mentioned that scoliosis following empyema may be of two separate types, the one due to a greatly thickened and contracted pleura (often actually calcified) and the other due to fusion of two or more ribs on the concave side of the curve.]

Bisgard states that both pleurogenic and thoracoplastogenic scoliosis are preventable and are curable if corrected in their incipient stages

542. Bisgard, J. D.: Deformities of Chest and Spine Resulting from Thoracic Disease and Operation: Their Prevention, Am. J. Surg. **54**:317-325 (Oct.) 1941.

but extensive and rigid deformities of the spine and the costal framework are incurable. He states:

> Pleurogenic deformities can be prevented by (1) the prevention of the formation of pleural scar by early cure of the empyema or pleuritis, and (2) the constant attention to maintenance of straight alignment or preferably of over correction of the spine. This can be accomplished by means of (a) postural wedging, (b) corrective body casts of plaster of Paris, and (c) resection of ribs on the side of concavity. To facilitate correction and the use of corrective measures, it is helpful to anesthetize the area of the wound by crushing the intercostal nerves which supply that area.

[ED. NOTE: It seems important to stress the postoperative care following thoracoplasty or empyema operations, as pointed out by Bisgard. The patients are usually treated by the thoracic surgeon and are not seen by the orthopedic surgeon until after a real problem of scoliosis has developed. Since most of the severe curvatures following these operations develop in children and because of the growth factor to be considered, it probably is important in some cases to continue the use of corrective plaster jackets and other measures as suggested by Bisgard for even longer periods, e. g. six to nine months postoperatively. It should be pointed out also that in some cases in spite of the best conservative care severe scoliosis may develop following rib resection for empyema or thoracoplasty, especially in children. It is necessary to resect fused ribs to correct some of these severe curvatures, and following correction of either type in the cases in which the condition is in a late stage spinal fusion is necessary to maintain any correction obtained in the curve. In some cases, especially those in which the patients are children, if severe curvature is expected to develop, it may be worth considering fusion of the spine before thoracoplasty.]

Schaefer and Purcell [543] state that it is possible to prevent entirely many of the cases of so-called idiopathic scoliosis or to preclude the aggravation of an existent curvature to be ameliorated if early diagnosis is made and treatment with desiccated thyroid instituted at its recognition. They point out that corrective orthopedic measures must be employed when gross deformity is demonstrated either by physical or by roentgen examination. The authors feel that treatment with desiccated thyroid is important in arresting the progress of so-called idiopathic scoliosis and quote Dr. H. L. Ulbrich's roentgen report to the effect that the epiphysial changes in the spine are the cause of progressive scoliosis and are of endocrine origin. [ED. NOTE: There is not sufficient evidence in this paper to warrant these conclusions.]

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543. Schaefer, R. L., and Purcell, F. H.: Juvenile Osteochondreal (Chondro-Epiphysitis) Hypothyroidism, Am. J. Surg. **54**:589-604 (Dec.) 1941.

Treatment of Scoliosis.—LeMesurier [544] reports a method for correcting the deformity in scoliosis before performing the fusion operation. The author states that the only thing really new in his paper is the use of the hammock for correcting the curve and holding of the patient while the plaster jacket is being applied. This method has been used in 27 cases and has been found to be considerably more satisfactory than the turnbuckle jacket. The author points out that the most satisfactory method available for treating scoliosis, particularly in those cases in which the deformity is already fairly marked and almost certain to become worse is the method that has been developed over a period of years at the New York Orthopaedic Dispensary and Hospital. There are three main principles that govern this method of treatment: first, to find out which is the primary curve; second, to make this primary curve as straight as possible, and finally, to stiffen this curve permanently in the straightened position by a fusion operation. The author states that the most difficult part of the whole treatment is the straightening of the primary curve. In most cases in which this method is used, the primary curve has become so stiff that it cannot be straightened completely. It can be improved a good deal, particularly toward its ends, by bending the spine in the opposite direction, but there is a limit to the amount of improvement that can be obtained. So far as the author has been able to find out by using different amounts of bending force and observing the results on roentgenograms, increasing this force straightens the curve until a certain point is reached; then the correction stops rather suddenly. Any greater force will not produce any further correction of the primary curve, although it may increase the more flexible secondary curves. [ED. NOTE: A greater force which did increase the more flexible secondary curve might be desirable in many cases in order to include some of the necessary compensation within the fusion area and therefore decrease the amount of compensation necessary below and above the fusion area.] The author states also that the Risser jacket can by a turnbuckle be made to exert a great deal of force but that this great force is not necessary and is sometimes dangerous. Besides involving difficulty of pressure sores, he feels that the whole method with the Risser jacket seems unreasonably complicated, requires a great deal of attention and takes a fairly long time before the patient is ready for the fusion operation. In an attempt to overcome these objections, the author reports the use of a hammock for the correction of these curvatures. The patient is placed in the hammock for an increasing length of time each day until he becomes

544. LeMesurier, A. B.: A Method of Correcting the Deformity in Scoliosis Before Performing the Fusion Operation, J. Bone & Joint Surg. **23**:521-532 (July) 1941.

used to the position, the two ends of the hammock being swung up to the ceiling with the body bent rather sharply in the direction to correct the primary curve. He points out also that this method is no more efficient in correcting the primary curve than is the Risser jacket, but the author believes that it is just as efficient and that it has certain advantages. He states that several attempts have been made to obtain more correction of the stiff curves than can be obtained by the hammock alone, but without success. [ED. NOTE: It should be pointed out that patients put up in this type of hammock have the head and the neck as well as the pelvis markedly flexed toward the side of the convexity of the primary curve. If turnbuckles are then placed in this position, it causes a great stretch on the neck, and it probably is impossible to obtain further correction without too much stretch on the cervical area.]

The author is, therefore, convinced that the stiff primary curves can be corrected to a certain limit by a moderate amount of bending force, and cannot be corrected further by any reasonable force that the patient can stand. The amount of bending force required to correct the curve to its limit can be as well obtained in the hammock, as it can with the turnbuckle jacket, or with any other mechanical force applied externally.

[ED. NOTE: This is an interesting paper, and the author presents a complete report of his method and shows roentgenograms of excellent correction by this technic. It is noted, however, that his illustrations show the patient markedly flexed toward the side of the convexity of the primary curve, with marked flexion of the cervical vertebra and especially of the head toward the side of the convexity. This suggests the possibility of cervical and brachial plexus problems or possibly subluxation of the cervical vertebrae as complications with this method. These may be fairly well controlled with the turnbuckle jacket method, especially when the turnbuckle jacket is applied with the patient's head and trunk flexed to the side of the concavity. When the turnbuckle jacket is used in this way, there will not be such sharp flexion of the head and the neck toward the side of the convexity with stretching of the cervical and brachial plexus during correction. The author's method has an advantage in that the patient can be flexed and corrected and the operation done without the period of correction in plaster requiring hospitalization for some weeks, as is usually necessary when the turnbuckle jacket is used. The method has, however, the disadvantage of including the whole leg and knee on the side of the convexity, therefore, immobilizing the knee and the ankle for several months. This method has been entirely satisfactory in the author's opinion, and it will be interesting to see whether it takes the place of the more commonly used turnbuckle jacket. In most hospitals in which the turnbuckle

jacket is used extensively and in large series of cases, the problem of pressure sores and other complications has been largely eliminated, so that as a rule this has not been a serious problem. It is true that in some cases correction can be easily achieved, especially those in which there are mild curves, and the hammock method of treatment described in this article may be satisfactory in cases of that type. However, it is likely that the turnbuckle jacket will continue to be used, especially in cases in which the condition is severe in which an attempt to obtain the maximum amount of correction should be made. Although a comparison of the two methods has not been made in a large series of cases presenting difficult problems, it seems most likely that the turnbuckle jacket method would obtain better results in cases in which the condition is severe when one considers the mechanical forces being used.]

Shands and associates [538] report an end result study of treatment of idiopathic scoliosis. This study included 425 case histories with roentgenograms and photographs. End result physical examination was made of 127 of the patients. The cases were reviewed from the standpoint of end results in sixteen orthopedic clinics throughout the country so that the report gives a good cross section of the methods of treatment, end results and various other statistics summarizing many of the present concepts regarding the treatment of idiopathic scoliosis. This is an excellent report and should help to clarify many of the problems of scoliosis. Some of these statistics confirm the previously noted observations, such as the facts that cosmetic deformity is the chief complaint, that the patients generally have no other symptoms, that it is a disease appearing most frequently at the age of puberty and predominating in girls 4 to 1 and that the curve is to the right in about 80 per cent of the cases, most commonly in midthoracic region. In this series all types of treatment were used, symmetric and asymmetric exercises, supports, correction and fusion and combinations of all types. Fifty per cent (214) of the patients reviewed had fusions done either immediately or after conservative treatment had been abandoned in favor of operation. Correction was by means of turnbuckle jacket in 80 per cent of those corrected and fused. The average percentage of those fused was 65, and the average percentage at end result examination was 27.

It is interesting to note that the patients showed considerable variation in the period of recumbency and that there was much less loss of correction in those kept recumbent three to six months and over postoperatively. Recumbency for six months or more did not seem to reduce materially loss of correction in this series.

. . . It was generally felt that immobilization during recumbency in plaster jackets is the best method of maintaining correction. Support should be continued after the patient becomes ambulatory for a total period of 7 to 9 months to

allow fusion mass to become solid since it must resist not only the strain of superincumbent weight but the tendency of contractures to pull the spine back to the deformed position. Ordinary back braces apparently do not maintain correction during this period unless they incorporate some lateral force as well as support. The results also show that those in whom fusion was less than the primary curve lost more than those in whom all the primary curve was fused. The greatest amount of correction was maintained in those patients in whom the area of fusion included more than the primary curve.

In patients in whom the extent of fusion was less than the primary curve 75 per cent lost 0 to 35 degrees. When the fusion was the same as the primary curve, 94 per cent lost 0 to 35 degrees, and when fusion was greater than the primary curve, 95 per cent lost 0 to 35 degrees.

[ED. NOTE: It is generally accepted that the primary curve is the minimum fusion area, and when less than this area is fused, the curve may definitely increase or lose correction for this reason. Loss of correction when the whole or more than the primary curve is fused must be due to inadequate fusion operation technic, failure to maintain the corrected position for a sufficient time or actual failure of fusion with pseudarthrosis.]

This report also reveals a high percentage of pseudarthrosis, a total of 60 cases, or 28 per cent, among 214 cases in which fusion was done for scoliosis. [ED. NOTE: This is a high percentage of pseudarthrosis following fusion for scoliosis. It is interesting to note that the percentage was lowest following the McKenzie-Forbes procedure—23 per cent. It should be noted that these figures cover the operations done by many surgeons over a long period of years during which the method of fusion has changed considerably. The results following fusions during the past few years show a much smaller incidence of pseudarthrosis, at least in some clinics.]

This study reports that complete correction was gained in only 5.5 per cent of the cases in which correction was done; all of the correction was maintained in 8 per cent, and there was complete loss of correction in 29 per cent. [ED. NOTE: It is of course obvious that only the relatively milder curves can be completely corrected and that the tendency to loss of correction should be less in these milder curves following correction than in the more severe curves.]

Results in 69 per cent of the cases were rated fair or poor, and in 31 per cent, good or excellent. [ED. NOTE: There are of course many factors to be considered which may influence end results in a series of this type. In some clinics fusion was done only in cases in which the condition was severe, and in others mild curves were fused. The age at which correction is done must also be considered. It is interesting to note that of the group treated by the Risser method between the ages of 12 and 15, 50 per cent showed excellent or good results

at the age of 12; 43 per cent, at the age of 13; 40 per cent, at the age of 14, and 50 per cent, at age 15, whereas for the total group only 31 per cent showed good or excellent results.]

The conclusions of this study are as follows:

1. Practically none of the patients with scoliosis are cured, if correction of lateral deviation is a criterion.

2. In approximately 60 per cent of those treated by exercises the deformity increased and in 40 per cent it remained unchanged.

3. Correction without fusion resulted in complete loss of correction after support was discontinued, in the majority of instances.

4. Correction by the turnbuckle jacket and subsequent fusion has yielded better results in this series than have other types of treatment.

[ED. NOTE: This report indicates the need for a great deal more work on the problem of the treatment of scoliosis. As pointed out in this report, the cosmetic deformity was the major problem, and the results of treatment were poor considering the entire group, at least from a cosmetic point of view. This brings out the point that the only real cosmetic improvement is obtained by correction and fusion. It seems, therefore, that from this point of view the correction and fusion must be done fairly early. It should also be mentioned that in a large percentage of cases the fusion is done to prevent further progress of the curve. If the curve is increasing when fusion is done, more has been obtained than mere cosmetic improvement of the existing curve. In considering the end results in the cases in which fusion was not done, one must take into account the fact that in a great many cases there is no increase and no operation is required. There is more and more evidence to support the view that either no treatment is needed or correction and fusion are indicated. Undoubtedly better cosmetic results and a greater percentage of correction could be obtained, and maintained, if all of the cases in which fusion is done were selected from cases in which the condition is relatively mild. The question must be raised, however, whether a large percentage of the patients could not do just as well without fusion and without any treatment.]

McElvenny[545] discusses the principles underlying the treatment of scoliosis. He attempts to explain the theory of this method of treatment by assuming a simple dorsal curve and trying to explain the development and treatment of this curve. In preparing this paper the author has made free use of the material offered in the fundamental articles by Ferguson and by Butte. He reviews the generally accepted principles of careful follow-up during the growth period and discusses the indications for operation and selection of patients for operation.

545. McElvenny, R. T.: Principles Underlying Treatment of Scoliosis by Wedging Jacket, Surg., Gynec. & Obst. **72**:228-236 (Feb.) 1941.

The author discusses the principles of correction and selection of the primary curve and the fusion area. Numerous illustrations to point out the primary curve, the marker film, the pelvic tilt roentgenogram and the selection of the primary curve are shown. Diagrams are used to illustrate the primary curve, the fusion area and the method of avoiding overcorrection of the primary curve or fusion of too long an area. [ED. NOTE: This is an excellent article on the subject of scoliosis and is worth reviewing by any one interested in the problem of scoliosis. It helps to explain some of the more complicated problems involved in the treatment of scoliosis, especially of this one particular type of simple curve. It is perhaps worth mentioning, however, for the benefit of those who have not treated a great many patients with scoliosis, that there are some cases in which there appears to be a typical single right dorsal curve and in which the lumbar curve may not be completely correctible. In some of these cases even though the principles outlined in this article are followed, it is possible for the so-called secondary or compensatory curve below the primary curve to develop the same characteristics as the primary curve, the result being what probably was originally a double primary curve and the lower curve increasing although the upper one was fused. The lower curve may continue to increase in the lumbar area as the patient grows although the dorsal curve has not been overcorrected at the time of operation and has shown no increase for a year or more later. This type of curve represents a difficult problem, especially in those patients treated in the younger age group in which there are several years of growth and possibility of increase in the so-called secondary curve even though the primary curve has been corrected and not overcorrected. The principles described in this article should be reviewed in the original article; they cannot be adequately abstracted without the illustrations and complete discussion. This is an excellent article.]

Steindler [546] points out that the treatment of scoliosis is a compromise, since complete automatic muscle control stability and mobility can be accomplished in only rare instances. The author believes that this compromise is acceptable for three reasons:

> The important factor in the deformity is not the curve itself, but rather the loss of posture which it involves—the lack of alignment between the head, shoulders and pelvis—so even if it is not possible to restore the anatomical form of the column, it is possible in a majority of cases to approach a normal posture. We call this the realignment of the spine by compensation.
>
> 2. When this passive realignment is once obtained, the musculature can in a great many cases be adequately developed to maintain actively the posture so regained, even though the mobility of the spine has been greatly reduced by the scoliosis.

546. Steindler, A.: Conservative Compensation-Derotation Treatment of Scoliosis, J. Bone & Joint Surg. **23**:67-80 (Jan.) 1941.

3. In the absence of adequate musculature, the entire mobility of the spine can be sacrificed by fusion, and the posture thus maintained passively.

In any event, restoration of alignment or posture is a necessary prerequisite. The question then is whether the two pre-requisites of successful conservative treatment—the degree of compensation necessary to restore posture or general trunk alignment and the degree of muscle function required to maintain it actively are available.

The cases of scoliosis are divided into five groups:

1. Those in which realinement or compensation occur spontaneously.

2. Those in which adequate compensation can be accomplished by conservative means.

3. Those in which adequate compensation can be maintained and in which adequate muscle power can be developed but in which because of marked adaptive or congenital osseous changes and in spite of good musculature compensation is likely to break down again.

4. Those in which alinement is possible, but no adequate muscle tone can be obtained. This includes most cases of paralysis. The spines in these cases also should probably be fused.

5. Those which cannot be adequately realined because of severe structural deformity.

The compensation-derotation treatment is described, and the indications and the contraindications for treatment are pointed out. The conclusions are as follows:

1. Compensation of the scoliosis is a necessary prerequisite for maintenance of correction and posture.

2. The combined compensation-derotation method is adequate to obtain compensation in suitable cases and leads to definite maintenance of posture.

3. The rotary deformity of the thoracic spine cannot be corrected at present. Attempts to correct the thoracic deformity by rotation to the concave side are preposterous. The thorax is already rotated to the concave side in relation to the spinal column, and such attempts only make the situation worse.

4. Derotation is directed toward the lumbar and cervicothoracic sections of the spine, and, by limbering up these sections, aids in the development of adequate counter curves.

5. If the compensation can be accomplished without forcible cast correction, and provided muscle development is adequate, the spine need not be fused. However, if the compensation must be forced by a cast, fusion will become necessary to hold the correction obtained.

6. Failure must be expected, with or without fusion, when compensation is lost or not obtained. Only a few cases at the end of the growth period hold the correction when decompensated.

7. Failure must also be expected in the absence of adequate muscle development, unless fusion is performed.

8. Compensation-derotation plus adequate muscle development promises success in the great majority of all non-paralytic cases.

9. Adequate compensation-derotation plus fusion in the presence of inadequate musculature, likewise, holds out promise of success in all paralytic and many congenital cases.

[ED. NOTE: Any curvature of the spine must have compensatory curves for adequate alinement of the trunk. These compensatory curves will develop in any patient without treatment of any kind. An increasing number of orthopedic surgeons and physical therapeutists believe that symmetric postural exercises will obtain this necessary compensation, and as yet there has been no study to show whether or not the compensation-derotation treatment offers any better results than the routine symmetric postural exercises. It is believed that routine symmetric postural exercises will improve the posture, increase vital capacity and improve the patient's general appearance and general health. However, it is doubtful whether any of these conservative treatments have any significant effect on the progress of the curvature. Exercises to strengthen the trunk muscles naturally help the posture and prevent back fatigue. In considering the problem of scoliosis there is increasing evidence that the majority of patients need little if any treatment except observation to determine whether there is any increase in the curvature or correction and spinal fusion if the curvature is severe or progressing. There are of course other indications for operation, such as pain, cosmetic appearance, instability (especially in cases of poliomyelitis).]

Vom Saal [547] reviews the management of scoliosis but discusses mainly the operative treatment which is used in most clinics. He discusses also the causation of scoliosis and apparently believes that poliomyelitis scoliosis "may be caused by either back, abdominal, hip or shoulder girdle paralysis." In the discussion of the treatment of scoliosis the author states that "if the patient is 15 or 16 years old a comparison of her height with that of other members of the family suggests that she has about obtained her growth, simple support is all that is necessary." [ED. NOTE: The author implies that the progress of idiopathic scoliosis depends on increase in growth, and this is doubtful in view of recent studies. It is also questionable whether any support is necessary at all for patients with idiopathic scoliosis beyond the age of 16. Also, as noted elsewhere in this review, it is difficult to see how paralysis of the shoulder girdle muscles alone can cause scoliosis, except perhaps occasionally a mild functional type which needs no treatment.]

Cohen [548] reports an anatomic study of the relevant section of the vertebral column of a 10½ year old girl who had undergone a Hibbs spine fusion for scoliosis. The second stage spine fusion had been completed seven and one-half months prior to death, and the exact cause of death was not known except that at autopsy marked gastric dilatation

547. vom Saal, F.: Management of Scoliosis, Am. J. Surg. **52**:433-442 (June) 1941.

548. Cohen, L. J.: Anatomic Findings Following Hibbs' Spine Fusion for Idiopathic Scoliosis, Bull. Hosp. Joint Dis. **2**:114-118 (July) 1941.

was found. The author discusses this problem and quotes Lehman, who reported cases of more or less pronounced ileus, one with a fatal issue, occurring after fracture of the vertebra, the pelvis or the ribs. In Lehman's cases the paralytic ileus always occurred soon after the injury. Cohen's study showed that all of the vertebral joints were not completely obliterated, yet there was sufficient new bone formation between the laminas to indicate a successful fusion and the essential maintenance of the correction. [ED. NOTE: It is interesting to note that this patient had a solid fusion seven and one-half months postoperatively, and yet the small articular facets were not all solidly fused. This tends to bear out the opinion of many who believe that fusion of the articular facets is not necessary for a solid spinal fusion. However, the significance of the facets in this particular case might be questioned in view of the fact that the child was 10½ years of age and would normally be expected to have a fairly solid fusion. This is one of the few pathologic reports on the study of spines fused for idiopathic scoliosis by the Hibbs method.]

Ruhlin and Albert [549] report 7 cases of scoliosis complicated by spinal cord involvement selected from a series of 2,000 cases of scoliosis of all types, and their conclusions are as follows:

1. The level of the apex of the curve shows no correlation with the distribution of the neurological changes.

2. All motor changes are of the spastic type.

3. There is no definite sequence in the appearance of the sensory or motor manifestations.

4. Conservative therapy shows little, if any, permanent improvement in the neurological status; therefore, laminectomy should be performed if a short period of conservative treatment fails to relieve the signs and symptoms present, or if the neurological signs increase, whether the sensory or motor changes are in precedence.

5. Laminectomy incisions should be drained.

6. In this series progression of signs and symptoms following laminectomy developed in all patients, but receded after a variable period, except in case 3. This patient did not regain function.

7. Laminectomy offers the best prognosis in case of scoliosis with signs of compression, despite the fact that torsion and tension are the etiological factors of these signs.

8. It is desirable to combine fusion with laminectomy when the patient's condition will stand this added operative procedure. The fusion should extend from horizontal vertebra to horizontal vertebra. The combined method of Steindler is a rapid procedure which has proved satisfactory. There may be an increase in the curve if solid fusion is done before the end of the period of rapid growth.

[ED. NOTE: This is an interesting series of cases representing one of the rarer complications of scoliosis. In several large clinics of 2,000

549. Ruhlin, C. W., and Albert, S. M.: Scoliosis Complicated by Spinal Cord Involvement, J. Bone & Joint Surg. **23**:877-886 (Oct.) 1941.

or more cases, few, if any, cases of spinal cord involvement have been noted. The condition is fortunately rare. It should be noted that the authors state that "there may be an increase in the curve if solid fusion is done before the end of the period of rapid growth." It is generally believed that if the primary curve is solidly fused between parallel lines there can be no increase even during the period of rapid growth unless there is some failure within the fusion area.]

Vertebral Epiphysitis.—Hodgen and Frantz [550] discuss the problem of juvenile kyphosis. They discuss briefly the clinical picture, speculations as to causation, pathologic nature and treatment and present a study of 50 cases. The most frequent age of onset was between 10 and 11 years. Contrary to some observers, the incidence was found to be greater in girls, being 78 per cent. They found the condition twice as frequent in the thin children of the asthenic constitution as in the short stocky pyknic persons. They describe the typical picture as generally consisting of a rounded back with limited mobility, a relaxed abdomen, increased lordosis and hyperextension at the knees. They state that in their experience they have not seen the severe rounded kyphos pictured in foreign publications. They also point out that the chest is more or less flat and plays a minor part in breathing.

[Ed. Note: It should be pointed out that round back must be divided into functional and structural the same as lateral deviations of the spine or scoliosis. Patients with round back due to poor posture tend to have a flat chest and round shoulders whereas patients with actual wedging of the vertebral bodies usually have a definite increase in the anterior posterior diameter of the chest, and the chest is frequently prominent anteriorly. In addition the structural round back shows marked convexity in the area of involvement on forward bending, whereas the round back due to poor posture tends to disappear and there is a long symmetric curve of the entire spine on forward bending, the spine usually being flexible.]

The authors discuss the conservative treatment of juvenile kyphosis but do not discuss the operative treatment.

[Ed. Note: It should be pointed out that as in scoliosis, probably the only treatment which will give satisfactory cosmetic results in some cases is correction and fusion before the deformity becomes too severe. One great difficulty in the problem of adolescent round back is the fact that there is a slow and insidious onset; by the time the child and the parents or the surgeon decide on operation there has already been considerable wedging of the involved vertebrae. This whole subject needs considerable further study in order to determine the cases in

550. Hodgen, J. T., and Frantz, C. H.: Juvenile Kyphosis, Surg., Gynec. & Obst. **72**:798-806 (April) 1941.

which increase is definitely to be expected and those in which spinal fusion should be done in the local area of vertebral wedging. Unlike scoliosis, round back usually involves only a relatively small number of vertebrae (sometimes only three to five vertebrae), and this whole area can be fused at one operation and without the elaborate correction involved in treating scoliosis if fusion is done sufficiently early. The spinal fusion operation can be expected to arrest the increase in kyphosis, but the cosmetic improvement is frequently relatively slight as the operation is so frequently done as a last resort at a time when the cosmetic appearance is already bad and correction of a dorsalis kyphosis is difficult.]

Adelstein [551] reports a case of extradural spinal cyst associated with kyphosis dorsalis juvenilis and presents 16 other cases collected from the literature. He believes that the clinical picture of an adolescent with progressive paraplegia together with erosion of the vertebral bodies in the midthoracic region as seen in kyphosis dorsalis juvenilis is pathognomonic of an extradural spinal cyst. He feels that all patients with kyphosis dorsalis juvenilis should be carefully examined for evidence of compression of the spinal cord and for roentgen evidence of enlargement of the spinal canal. He believes that the wedging seen in this condition with extradural cyst results from venous stasis secondary to the presence of the cyst. He points out that the causation of kyphosis dorsalis juvenilis unassociated with an extradural cyst is unknown. He believes that early surgical intervention with removal of the intraspinal cyst usually results in complete cure with relief of all signs of compression of the spinal cord and prompt arrest of the kyphotic deformity. [ED. NOTE: This is a good paper, and while the subject has been previously presented, it brings to attention again this interesting relation between kyphosis dorsalis juvenilis and spinal extradural cyst. There are undoubtedly many cases of kyphosis dorsalis juvenilis associated with spinal extradural cyst in which the presence of the extradural cyst is overlooked. As in other lesions of the spine there are probably several or many causative factors which may produce the same resulting changes in the vertebral bodies and the same relative roentgen picture. This perhaps should be mentioned since the paper is likely to imply that the spinal extradural cyst is common in kyphosis dorsalis juvenilis when actually it is one of the rare causes for this condition. This paper should stimulate further study on the subject of kyphosis dorsalis juvenilis about which so little is known at present.]

Schaefer and Purcell [543] express the opinion that vertebral epiphysitis or juvenile osteochondritis is due to hypothyroidism. They suggest

551. Adelstein, L. J.: Spinal Extradural Cyst Associated with Kyphosis Dorsalis Juvenilis, J. Bone & Joint Surg. **23**:93-101 (Jan.) 1941.

treatment with thyroid and apparently do not differentiate between idiopathic scoliosis and adolescent round back. [ED. NOTE: While some patients with juvenile osteochondritis may have a thyroid deficiency and while thyroid deficiency may be a factor in some cases, there is still insufficient evidence to conclude that thyroid deficiency is a major cause of this condition.]

Corsellas and Baila [552] discuss the problem of vertebral epiphysitis. They present a résumé of the literature and feel that the description of Calvé does not fit in with the symptoms. They prefer to call this lesion epiphysitis. They feel that this condition must be classified in the group of bone dystrophies of puberty and adolescence along with the other forms of epiphysitis, and they think that late rickets, aseptic necrosis and small repeated trauma in persons with endocrine insufficiency are the contributing factors in this disease. The authors emphasize the importance of differential diagnosis by roentgen examination between epiphysitis and early Pott's disease of the spine. They also present the differential diagnosis between epiphysitis and Marie-Strümpell arthritis and typhoid spondylitis. The authors consider the prognosis fairly good and suggest rest in bed and occasionally plaster beds for treatment. They also advise the giving of vitamin D and calcium as well as postural exercises. This article is illustrated with the patients at different ages, showing the characteristic roentgen appearance of the epiphysitis and the differentiation from Pott's disease and other conditions.

Osteochondritis of the Vertebra.—Kuhlman [553] briefly reviews the literature on vertebra plana. This condition was first described by Calvé as noted in children and similar in character to Legg-Calvé-Perthes disease of the femur and other osteochondritides. Since that time many different names have been applied, especially vertebral epiphysitis, juvenile kyphosis, osteochondritis deformans and osteochondritis of the vertebra. The disease is usually found in children 2 to 15 years of age, the greatest incidence being between 5 to 10 years. The author points out that the disease starts with slight narrowing of the vertebral body and an increase in the widths of the intervertebral disks with the latter not eroded or destroyed. The involvement is usually limited to one segment, although occasionally more than one vertebra shows involvement. The progress is usually rapid with flattening of the vertebra and continues until only a thin disk of bone remains. At this time the intervertebral disks adjacent are much wider than normal. The density of bone is usually well maintained, and at the end, when the

552. Corsellas, M. F., and Baila, A. E.: Vertebral Epiphysitis, Prensa méd. argent. **28**:598-611 (March 12) 1941.

553. Kuhlman, F. Y.: Vertebra Plana (Calvé): Report of Two Cases, Am. J. Roentgenol. **46**:203-206 (Aug.) 1941.

collapse is complete, the density is greater than normal. Regeneration of the body is said to take place without much new bone formation in the adjacent structures.

In some instances the contour of the vertebra has been reported to be completely restored in a year's time. Diagnosis rests on roentgen findings; in most cases the clinical diagnosis is tuberculosis of the spine. However, the roentgen picture is characteristic. The density of bone is normal or increased instead of decreased as in cases of tuberculosis. The intervertebral disks are wider than normal and are not involved, whereas in cases of tuberculosis the disks are usually the point of early attack and are destroyed. The regeneration is reported to be more rapid than in cases of tuberculous disease and more uniform in character; it occurs without fusion of the involved segments with the adjacent vertebrae. The author reports 2 cases; in one the patient was a girl aged 5 years and in the other a boy aged 8. Trivial trauma to the back preceded the onset of symptoms in both cases; the significance of this is not certain. There was a history of acute infectious disease prior to onset of symptoms in both cases; the significance of this is likewise uncertain. It is conceivable that trauma or infection or both were instrumental in introducing embolic or thrombotic phenomena in the nutrient vessels of the vertebra and that this in turn led to necrosis of the bone and collapse of the involved segment.

[Ed. Note: This is a good article and is well written. While it does not report any new condition, it again calls to attention a condition which is rare and which is usually confused with tuberculosis.]

Dorsolumbar Syndrome.—Slobe [554] discusses the dorsolumbar syndrome with special reference to referred pain. He states that

> The frequency with which fibrositis occurs in the mid-back (dorso-lumbar region) is not sufficiently recognized. Such pathology quite commonly gives rise to characteristic referred pain and the combination may well be called the "dorso-lumbar syndrome" to distinguish it from the frequent "sciatic syndrome" associated with low-back involvements.
>
> The literature is replete with articles dealing with low-back pain and the sciatic syndrome but relatively few articles emphasize the frequency of dorso-lumbar involvement.

The author uses the term "fibrositis" for lack of a better term to include myositis, fascitis, periarthritis, arthritis and other conditions, in fact any inflammatory or degenerative disease involving the muscles, the fascia ligaments, the periosteal insertions, the joints and the nerve sheaths. The author presents 4 cases to illustrate his point. He points out that tenderness of the testicle, the inguinal canal, the lower portion of the abdomen, the upper part of the thigh and the superolateral por-

554. Slobe, F. W.: Dorsolumbar Syndrome with Special Reference to Referred Pain, Illinois M. J. **80**:332-336 (Oct.) 1941.

tion of the buttock usually can be elicited, sometimes largely confined to one area, sometimes to several and sometimes over all these areas. He states that this association of severe pain with tenderness causes mistaken diagnoses of incarcerated hernia, appendicitis, renal colic, pelvic disease and other conditions, causing needless operations to be performed. He suggests the use of local anesthesia as a diagnostic as well as therapeutic aid.

[ED. NOTE: This article falls into the group reviewed in "Progress in Orthopedic Surgery for 1940" which dealt with the so-called viscerospinal syndrome, spinal appendicitis and other conditions. It is perhaps worth while to stress the importance of these cases of referred pain.]

Spinal Root Pain.—Eaton [555] describes the outstanding characteristics of root pain which are valuable in differential diagnosis and emphasizes these characteristics by considering the mechanics of the production of the pain. The author discusses the various kinds of root pain. He believes that dilatation of the veins in the epidural space with coughing, sneezing and straining dislocates the dura toward the spinal cord, stretches the enveloped nerve roots and thus produces pain. He points out that it has generally been assumed that such intensification of pain results from an increase in pressure from the spinal fluid. However, he notes that jugular compression rarely intensifies root pain unless the pain is due to a tumor of the spinal cord which produces dynamic subarachnoid block. He has made several tests with lumbar puncture and jugular compression to illustrate his point that increasing the pressure of the spinal fluid alone does not intensify root pain. He states that increasing the size of the epidural space with consequent displacement of the dura toward the spinal cord is the factor responsible for intensification of the pain by virtue of traction on the diseased nerve roots. He also explains root pain at night by spontaneous elongation of the spinal column during sleep. He attempts to prove this by measurement of several patients at the various periods of activity and sleep. One patient increased 60 mm. in height after sleeping.

Articular Process Fissures.—Oppenheimer [556] reports 4 cases of longitudinal fissures in the vertebral articular processes. He points out that

> Radiolucent gaps in the neural arch and its processes are known to be due to persistence of cartilaginous union and failure of bony union between parts which arise from distinct centers of ossification. Most of these so-called fissures are in the laminae, in the isthmus between the superior and inferior articular processes,

555. Eaton, L. M.: Pain Caused by Disease Involving Sensory Nerve Roots (Root Pain): Its Characteristics and Mechanics of Its Production, J. A. M. A. **117**:1435-1439 (Oct. 25) 1941.

556. Oppenheimer, A.: Longitudinal Fissures in Vertebral Articular Processes, J. Bone & Joint Surg. **23**:280-282 (April) 1941.

and at the tip of the inferior articular processes of the lumbar vertebrae. An additional fissure, apparently not yet recorded, was found in four persons. In each of them, it was associated with gaps at the tips of the articular process and, in one patient, with gaps in both the isthmus and the lamina of the same vertebra. It extended from the region of the isthmus along the longitudinal axis of the articular process down to the gap at its tip, the two fissures standing at right angles. . . . In all the cases the outlines of the longitudinal fissure were irregularly serrated, which suggested a fracture line. None of the patients, however, remembered having incurred an injury, and there were no signs or symptoms whatever referable to the spine. The gaps were discovered accidentally in roentgenograms of the digestive or urinary tract. Since there is only one center of ossification for the main part of each articular process, according to present knowledge, it would seem difficult to account for the longitudinal gap by a developmental failure of bony union. However, the constant combination with a second gap known to be due to such a failure, together with the absence of a history or clinical signs of trauma, is in favor of a developmental anomaly.

He points out also that longitudinal fissures are rare and that their incidence in his observations were as low as that of aplasia of articular processes (about 0.09 per cent of all spines examined). The significance of these longitudinal gaps seems to lie in the fact that they look like fracture lines. He states that fractures of the articular processes are rare, most of them being combined with fractures of other parts of the vertebrae. He observed only 3 cases of fracture of an articular process without other vertebral lesions; in each of them the clinical signs and symptoms were definite, and the trauma had been severe. In 2 of them there was radicular neuritis with atrophy of the corresponding muscles and bone, and in all cases the mobility of the spinal section involved was greatly diminished. The fact that a longitudinal fissure resembling a fracture line may exist in the complete absence of clinical manifestations may be worth recording, since increasing importance is given to roentgen findings in deciding on questions of treatment and of compensation after some relatively slight injury.

[Ed. Note: This is an interesting report and should be kept in mind by orthopedic surgeons in connection with compensation or medicolegal cases.]

Anatomy and Anatomic Variations of the Spine and Thorax.—Fuchs [557] presents an interesting study of the thoracic vertebrae with excellent illustrations of photographs of the individual vertebral bodies with comparable roentgenograms of these bodies in the varying positions. He identifies the various outstanding points on the roentgenograms and the photographs for clear interpretation of the roentgen shadows. He also points out the various anomalies, the landmarks to be noted and the technic for obtaining best visualization of the thoracic

557. Fuchs, A. W.: Thoracic Vertebrae, Radiog. & Clin. Photog. **17**:2-13, 1941.

vertebrae. [ED. NOTE: This article has beautiful illustrations and could well be included in any bibliography on the study of anatomy, anomalies and other orthopedic problems or roentgen technic. It is probably of more interest to roentgen technicians or to any one making a special study of any condition involving the thoracic spine, including scoliosis.]

Zadek [558] reports a tackhammer deformity of the sternoxiphoid cartilages causing gastrointestinal symptoms relieved by excision. The author states that he has been unable to find a record of a similar condition in the literature. The patient aged 39 complained of pain in the pit of his stomach. It occurred six months before examination without any history of previous injury. The pain was especially troublesome when the patient was in bed. It was acute when the patient was supine, and the most comfortable position was lying on the left side. When on occasions he had lifted a heavy object, the pain was so sharp that it caused him to drop the object. The condition progressed so that he could not eat normally, and he complained that everything seemed to catch in the pit of his stomach. The patient lost 35 pounds (15.9 Kg.) within six months. On examination there was no rigidity or spasm of the abdominal muscles. The patient had an unusually long xiphoid cartilage which was nearly 3 inches (7.6 cm.) in length. It was freely movable, and roentgenograms showed the fishtail appearance of the xiphoid process. The xiphoid process was removed at operation. It was found that the tip of the deformed process was cartilaginous and that the recti muscles seemed to catch as they were moved over these prongs laterally and medially. [ED. NOTE: This is an unusual deformity of the chest and is apparently rare or at least not frequently observed in orthopedic cases.]

Involvement of Ribs and Rib Cartilages.—Holmes [559] reports a study of slipping rib cartilage syndrome. He reviews the literature on this subject. This condition was first reported by Cyriax. The author points out that because of the failure to recognize this syndrome needless laparotomies are performed and prolonged suffering and incapacity from an easily curable condition are often permitted. Moreover there does not appear to be any clear conception of the development of this deformity. He points out that the deformity involves the cartilages of the lower ribs, notably the eighth, the ninth and the tenth, by displacement of fracture fragments or dislocation of the cartilage or more often by curling the end of the loosened cartilage so that on respiration or

558. Zadek, I.: Tack Hammer Deformity of Sternal Xiphoid Cartilage Causing Gastrointestinal Symptoms Relieved by Excision, Bull. Hosp. Joint Dis. **2**:111-113 (July) 1941.

559. Holmes, J. F.: Study of Slipping-Rib-Cartilage Syndrome, New England J. Med. **224**:928-932 (May 29) 1941.

motion the deformed cartilage end slips over or rubs against the inside of the rib above with a click which is felt by the patient and in some cases is accompanied by severe and incapacitating pain. The author reviews 33 cases, 15 already reported and 18 new cases. He concludes that the slipping rib cartilage occurs more frequently from indirect than from direct trauma. The author states that the diagnosis of slipping rib cartilage is made from the complaint of pain, usually in the rib border, and by digital examination with the patient relaxed and supine with the knees flexed, in which position the abnormally movable rib cartilage with its associated click and pain can be demonstrated. Limitation of chest expansion as demonstrated by measurement is also a suggestive diagnostic feature. The treatment of this condition as reported in the literature has largely consisted in excision of the rib cartilage involved and has been followed by immediate and complete relief of symptoms. The author concludes that slipping rib cartilage is an entity presenting a classical clinical picture. It often produces irksome and incapacitating symptoms. Following excision of the offending rib cartilage or cartilages, immediate and permanent cure was obtained in every case.

Hemangioma of the Vertebrae.—Ghormley and Adson [560] point out that vertebral hemangioma is a definitely recognizable condition which may not cause symptoms. However, the symptoms of some patients, particularly the younger ones, may be marked even to the development of complete paraplegia. In such cases laminectomy with decompression followed by roentgen therapy offers the best possibility of relief. For patients in whom paraplegia is not present but in whom there is evidence of compression of the spinal cord or local symptoms, roentgen therapy is the treatment of choice. Supportive corsets or braces should be used whenever they are indicated, e. g. for patients who have the static type of pain or sufficient involvement of the vertebra by the hemangioma to cause pathologic compression fracture. This complication, however, is rarely noted. The authors illustrate the roentgen picture of hemangioma of the vertebra and report a series of 39 patients, of whom 27, or 69 per cent, were female, 12, or 31 per cent, were male. One of the striking facts brought out in this review is the lower average age of patients who have had symptoms. The authors divide the condition into four types: (1) hemangioma with paraplegia; (2) hemangioma with symptoms of compression of the spinal cord but without paraplegia; (3) hemangioma with local symptoms and signs but without evidence of compression of the spinal cord; (4) hemangioma without any symptoms or signs. They describe the roentgen findings, pointing out that in the early phase of the disease there are areas of hypertrophy of the

560. Ghormley, R. K., and Adson, A. W.: Hemangioma of Vertebrae, J. Bone & Joint Surg. **23**:887-895 (Oct.) 1941.

pedicle and the lamina, enlargement of the intertrabecular spaces and absorption of trabeculae in the body with thickening of other trabeculae, thus giving the appearance of channels situated between or interwoven among the trabeculae. They state:

> In the more advanced stages of the disease, a ballooning process takes place, the body of the vertebra is flattened, and the walls have a tendency to bulge. This process accounts for the narrowing of the spinal canal. In a few instances a pathological fracture has occurred, which accounts for the kyphosis or scoliosis.

[ED. NOTE: This is a good article and summarizes the present knowledge of hemangioma of the vertebrae, presenting the indications for treatment and the treatment to be used.]

Intervertebral Disks of the Cervical Part of the Spine.—Stone, Arieff, Kaplan and Brown [561] present a case of multiple protrusions of the fifth and sixth cervical intervertebral disks.

> . . . The onset was sudden like that of an acute inflammatory lesion of the lower cervical region of the spinal cord. In four months a quadriparesis (left lower extremity completely paralyzed), dissociation of sensibility, atrophy of the hand muscles and a Horner's syndrome resulted. The findings of a complete spinal block, increased protein content of the spinal fluid and a questionable narrowing of the 6th cervical vertebrae were indications for neurosurgical exploration.

The authors state that protrusion or rupture of an intervertebral disk in the cervical region is not common and that multiple protrusions in this region are less common and may simulate a syndrome complex of acute inflammation, syringomyelia or spinal compression.

Rupture of Muscles of the Abdominal Wall.—Sileo [562] reports a case of spontaneous rupture of the external and internal oblique muscles with hematoma of the abdominal wall. He points out that the diagnosis of spontaneous hemorrhage into the abdominal muscles is difficult to make. Recognition of the condition is made difficult because palpation usually gives no evidence of the intramuscular location of the tumor. When the hematoma is removed, the condition usually subsides rapidly. In view of the difficulty and the uncertainty of the diagnosis and the doubtful results of conservative therapy, operation is recommended for use in all cases. Conservative treatment should be employed only when the insignificance of the findings does not warrant surgical intervention. [ED. NOTE: Probably most of these patients would come under the care of the general surgeon rather than of the orthopedic surgeon.]

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561. Stone, T. T.; Arieff, A. J.; Kaplan, L. A., and Brown, C.: Protrusion of Two Intervertebral Disks in Cervical Region: Report of Case, J. Nerv. & Ment. Dis. **93**:719-722 (June) 1941.

562. Sileo, J. A.: Spontaneous Rupture of External and Internal Oblique with Hematoma of Abdominal Wall, Bull. New York M. Coll., Flower & Fifth Ave. Hosp. **4**:55-58 (June) 1941.

Odontoid Process.—Wade [563] reports a case of backward and lateral displacement of the odontoid process which simulated a case of platybasia. This is an unusual case as the injury occurred thirty years before death. It is an interesting report of the clinical and autopsy observations on a patient who had a persistent bilateral lesion of the pyramidal tract attributable to injury sustained thirty years before her death. It is of interest that the degenerative changes in the pyramidal tracts below the site of compression were greatest on the left side, even though the infarct was in the left internal capsule. The left side of the cord was in nearest proximity to the odontoid process. There had been a rupture of the transverse axis ligament with displacement of the odontoid process and compression of the cervical cord.

XIV. CONDITIONS INVOLVING THE HIP JOINT

Osteochondritis of the Head of the Femur.—There is still considerable disagreement as to the causation of osteochondritis. Traumatic, bacteriologic and endocrine factors have each received varying emphasis. The question is naturally one of extreme importance for the establishment of a rational basis of therapy. Two new articles which approach the subject from this standpoint have appeared in the literature of the past year. The first is an attempt to correlate Legg-Perthes disease, coxa vera, osteochondritis dissecans and other conditions under a single mechanistic theory; the other emphasizes hormonal deficiency.

Bozsan,[564] in a lengthy article in which he follows the historical development of the idea, states that osteochondritis dissecans of the femoral head, several forms of coxa vara, Legg-Perthes disease, slipping of the femoral epiphysis, ischiopubic and acetabular osteochondritis are all related and are the result of traumatic compression of cancellous bone. This conception of the pathogenesis is one which the author states will clear the prevailing confusion and facilitate the understanding of the grosser features of the whole group if given the key position it merits. The conception is an ingenious one supported by pathologic, radiologic and clinical material although perhaps somewhat lacking in experimental evidence. The author believes that the characteristic wedge-shaped areas of aseptic necrosis may be produced by a mechanism other than infarction, namely, by compression of spherically shaped portions of cancellous bone. Such compression of spherically shaped bodies causes damage

563. Wade, L. J.: Pseudoplatybasia, Rupture of Transverse Ligament of Axis with Displacement of Odontoid Process and Compression of Cervical Cord, J. Bone & Joint Surg. **23**:37-43 (Jan.) 1941.

564. Bozsan, E.: Compression of Cancellous Bone: Principal Manifestations in Head and Neck of Femur; Treatment by Connecting Drill Channels, Am. J. Surg. **53**:567-618 (Sept.) 1941.

in an area which is wedge shaped on cross section but which in actuality corresponds to a cone the base of which lies at the site of the application of the force. The compression does not damage the entire substance of the cone but is most effective in its peripheral extent and produces within the compression pattern secondary component wedges. Each impact produces its own wedge, and the compression pattern varies with changes in the curvature of the surface and speed of force resulting in various combinations of superimposed patterns. These effects are illustrated by analogy with the bruising of an apple and by the roentgen appearance of osteochondritides.

On this conception the author bases his therapeutic principles which essentially consist of drilling the compression barrier to facilitate the healing process. The therapeutic results are illustrated by 23 cases of the group of diseases which he believes are due to this process.

The second article is that of Schaefer and Purcell,[565] who contend that the so-called juvenile chondroepiphysitis is due neither to an inflammatory process nor to vascular changes but is specifically due to hypothyroidism with consequent lack of tissue-differentiating factor. They suggest that the confusing terminology be done away with, and they propose with more certainty than present knowledge will perhaps warrant that the entire group be given the name osteochondral hypothyroidism. The authors' contention has been fully developed in a former study,[566] and the present article deals with results of treatment in a series of 27 cases with desiccated thyroid.

They divide hypothyroidism into primary and secondary types. By primary is meant a clinical disturbance in which no signs of dysfunction can be determined except those referable to the thyroid. The authors imply that in cases of secondary hypothyroidism the primary failure is of a gland other than the thyroid, such as the hypophysis, resulting in growth or sex disturbances together with the associated and determinable signs of thyroid deficiency. The authors' requirements for the diagnosis of hypothyroidism, either primary or secondary, are the usual ones, namely, clinical history, developmental delay, decreased basal metabolic rate below — 10 per cent, increased blood cholesterol above 200 mg. per hundred cubic centimeters of blood and the presence of chondroepiphysial changes.

Of the 27 cases reported, there were 2 of Legg-Perthes disease, 2 of slipped capital femoral epiphysis, 10 of Osgood-Schlatter disease, 6 of calcaneoapophysitis, 2 of Kohler's disease and 5 of epiphysitis of the

565. Schaefer, R. L., and Purcell, F. H.: Juvenile Osteochondreal Hypothyroidism, Am. J. Surg. **54**:589-604 (Dec.) 1941.

566. Schaefer, R. L.; Strickroot, F. L., and Purcell, F. H.: Endocrine Implication of Juvenile Chondroepiphysitis, J. A. M. A. **112**:1917-1919 (May 13) 1939.

spine. The patients' ages ranged from 5 to 15 years, and the authors claim that all displayed definitely related symptoms and that the roentgen diagnoses were unbiased, being made by a cross section of capable roentgenologists. All patients received routinely desiccated thyroid in full therapeutic doses by mouth, and in addition those displaying other signs of endocrine dysfunction, such as delayed pubescence, were treated with chorionic gonadotropin. Obesity was corrected when present, and all patients were ambulatory. Orthopedic treatment is regarded as adjunctive. Only 1 patient with Osgood-Schlatter disease required immobilization for two weeks.

The authors feel that normal ossification of the epiphyses was hastened as indicated by subsequent roentgenograms and that clinical cure was effected more rapidly.

Ischiopubic Osteochondritis.—Steinsleger [567] reports 2 cases and Garcia and Nespolo [568] 3 cases of this condition. They all emphasize that differential diagnosis may be difficult. Steinsleger points to the value of a secondary roentgenogram taken a few months later which demonstrates reparative processes not seen in cysts or bone tumors. The condition may make its appearance between the fifth and the twelfth year, although the conjoint ramus usually closes at approximately the ninth or the tenth year, and this suggests that in some instances the closure is delayed by the pathologic process. The condition is of interest because it may give rise to vague hip symptoms which may lead to wrong diagnosis and radical treatment for a condition which is benign and which can be cured in a relatively short time by simple rest and recalcification therapy.

Slipping of the Capital Femoral Epiphysis.—Thrap-Meyer [569] reports that all of the literature which he has reviewed contains no mention of a single instance of slipping of the capital femoral epiphysis in several members of the same family or in more than one generation. He reports 1 case in which both the father and the son showed a slipping of the epiphysis of the head of the femur. He draws no conclusions from this case but suggests the theoretic possibility of a hereditary factor in the causation of this condition.

Forrester-Brown [570] reports the end results of conservative treatment of slipping of the upper femoral epiphysis. He emphasizes that the

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567. Steinsleger, M.: Ischiopubic Osteochondritis, Bol. Soc. de cir. de Rosario **7**:485-491 (Nov.) 1940.

568. Garcia, A. L., and Nespolo, J. S.: Ischiopubic Osteochondritis: Cases, Semana méd. **1**:1136-1141 (May 15) 1941.

569. Thrap-Meyer, H.: Epiphysiolysis Capitis Femoris in Two Generations: Casuistic Report, Acta orthop. Scandinav. **11**:1-10, 1940.

570. Forrester-Brown, M.: Slipping of Upper Femoral Epiphysis: End Results After Conservative Treatment, J. Bone & Joint Surg. **23**:256-262 (April) 1941.

object of treatment should be to obtain a joint the range of motion of which, however limited, is through the most valuable or important arcs rather than a perfect reduction as shown by roentgenograms with a flexed, abducted or adducted limb. There is usually a gradual increase in the range of motion over a period of years following conservative treatment, whereas patients treated by more radical measures often show good results at first with a gradual progression of stiffness over a long period.

Of the author's 22 patients, 19 showed definite endocrine abnormality, some with increased sugar tolerance. These patients were given thyroid, and some were given thyroid and injections of whole pituitary. Definite improvement was noted. The author feels that there is a frequent generalized and persistent softening of bone in these cases as demonstrated by the frequency of severe knock knee as a complication which is much aggravated through spasm of the adductor muscles of the thigh. The presence of knock knee is one of the factors which make treatment without abduction of the hip desirable.

Heavy traction was used as a preliminary in some of the writer's earlier cases, but the result proved disappointing, the only result being that the weights pulled the hip below its normal level in the acetabulum without effecting any change in the relation of the head to the neck.

The technic used was essentially that of Leadbetter, a general anesthetic being given in nearly all cases. An attempt is made to rotate the limb internally and extend it without losing the internal rotation. A normal amount of internal rotation is usually accomplished. A plaster spica cast is applied to maintain extension with a minimum of abduction. The foot is included in order to control the internal rotation. The patient is allowed up and about as soon as the cast is dried. The plaster fixation is maintained until definite trabeculation is seen to cross the epiphysial line.

Serial roentgenograms of these patients taken every few months for a period of years after manipulation show progressive reconstruction of the upper end of the femur by which the line of weight bearing is gradually deflected into normal lines with increased density of new trabeculae. In all cases full extension of the hip and internal rotation to neutral were maintained. In 1 case the internal rotation was increased beyond normal. All patients walked with a normal attitude, but all had some limitation of flexion. They were able to sit without discomfort. Nine of the 22 patients had limitation of abduction and adduction and of external rotation. Only 1 had a full range of motion in all directions.

In the author's opinion this simple method of treatment gives good functional hip joints, and the results compare favorably with those of methods which are more difficult to carry out and more dangerous to life and limb.

Howorth [571] reports the end results of 132 cases which were the subject of a communication eight years previously.[572] Half of the children were not of the endocrine type, but 65 per cent were definitely tall or overweight. Trauma of a sufficient degree to cause epiphysial displacement was rarely present.

Four stages of the disease are described. These are the preslipping, the slipping, the quiescent and the residual stage. The condition is quiescent when symptoms and signs have subsided and is residual when there is complete bony union at the epiphysial line. The author found the leukocyte count of the blood to be 10,000 to 12,000 in half of the cases without an increase of the polymorphonuclear percentage. The erythrocyte sedimentation rate, however, was above 10 mm. per hour in 90 per cent of the cases, and in 1 instance it was as high as 40 mm., the average being 25 mm. Downward displacement of the head is regarded by the author as more serious than posterior displacement, for limitation of motion and arthritic changes are more common. He states that circulatory changes in the head are rare unless the head has been separated from the neck by surgical means. Of the 70 patients operated on, 17 were in the preslipping stage. In the preslipping stage the capsule was usually found to be edematous and thickened and the periosteum and the synovial membrane to be thick, red, softened and vascular with a tendency toward pannus formation. Softening of the epiphysial disk could be discerned with the aid of an instrument. Cultures of the soft tissues and of the synovia were consistently negative.

In the slipping stage there was usually a fold of soft redundant synovial membrane in the posteroinferior angle, and pannus formation was usual. In no instance was there actual separation between the head and the neck, even in those cases in which opening was done immediately after slipping. A layer of firm, fibrous or cartilaginous tissue covered the exposed portion of the end of the neck and joined it to the cartilage of the head. Usually the distal part of the epiphysial disk was soft, but in later stages it was firm and sometimes solidly ossified. Callus of varying degrees of maturity filled the posteroinferior angle.

In the author's opinion the primary pathologic condition is synovitis of the hip during rapid growth which causes circulatory disturbances of the epiphysial disk which results in its decalcification and softening with subsequent slipping. The cause of the synovitis is not proved, though the clinical and the pathologic picture and the alternating sedimentation rates suggest infection. The negative cultures are explained as being possibly due to difficulties of culturing the organisms or the virus involved.

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571. Howorth, M. B.: Slipping of Upper Femoral Epiphysis, Surg., Gynec. & Obst. **73**:723-732 (Nov.) 1941.

572. Ferguson, A. B., and Howorth, M. B.: Slipping of Upper Femoral Epiphysis: Study of Seventy Cases, J. A. M. A. **97**:1867-1872 (Dec. 19) 1931.

In the quiescent and residual stages correction of the deformity by subtrochanteric osteotomy is preferred because there is less likelihood of secondary damage to the head. As he stated in the previous study, closed reduction by manipulation was unsatisfactory, for in the majority of cases permanent limitation of motion following prolonged immobilization was the rule. Reduction of the epiphysis by strong traction was attempted early in 7 cases. The downward displacement was corrected in most of them, although usually the rotation could not be overcome. All of the epiphysial disks healed well, but the cortex of the head was irregularly ossified and the joint space thinned. Final motion was good in only 1 case, fair in 1 and poor in the remainder. Howorth believes that the poor results are due to injury of the capsule and of the circulation by traction. Eleven open reductions, 6 of them osteotomies through the proximal end of the neck, were reported in the first series. These were performed some weeks after slipping. In the later series 17 open reductions were done through the epiphysial disk. Eleven of the patients were immobilized in plaster for ten to twelve weeks. There were only 2 who showed good results, both having had preliminary rest with light traction. There were 2 complete failures, one requiring fusion and the other arthroplasty at a later date. On the remaining 6 who had open reduction, internal fixation with the Smith-Petersen nail and the Lippman screw was done also. The results were far better, in 2 cases being good, in 3, fair, and in 1, poor. Follow-up averaged two and one-half years. However, of a total of 28 hips on which open reduction was performed, 5 showed good results and 9 showed fair results, leaving 14, or 50 per cent, showing poor results. Internal fixation with early active motion is preferable when open reductions are done. A preliminary period of rest in bed with light traction is advantageous.

The author at first felt that if the patient were kept in bed in the preslipping stage so as to avoid weight bearing the slipping would not progress and the lesions would heal. However, in patients who had been kept in bed for several months, the slipping occurred suddenly as soon as weight bearing was resumed.

The drilling operation was later used in 17 cases in an attempt to produce premature union in the preslipping stage and in 23 cases with slight displacement. The Smith-Petersen approach was used. Several holes were drilled, curetted or gouged from the neck across the epiphysial disk and into the head. Long and thin slivers of bone taken from the ilium were inserted into these holes. Owing to technical errors there were 3 initial failures in a total of 40 cases. In 2 cases bone pegs were not used, and in these union was slow. In the remaining 35 hips, however, the lesion healed in from eight to twelve weeks, and bony union was complete within six to twelve months.

Aseptic Necrosis.—Banks [573] reports 9 cases of aseptic necrosis of the femoral head following traumatic dislocation of the hip. The reappearance of symptoms after an early period of apparent recovery is now known to be due to aseptic necrosis of the head of the femur; this results from a disruption of a major portion of the blood supply of the femoral head at the time of the dislocation. The author emphasizes that while death of the femoral head occurs shortly after the dislocation it cannot always be detected by roentgenograms at the end of six weeks when the patient is ready to resume walking. Ordinarily from three to four months are required for sufficient atrophy to occur before the contrast between living and dead bone is distinguishable in roentgenograms. Spontaneous reduction of a subluxation of the hip joint occasionally occurs immediately after the trauma so that the initial roentgenograms may appear entirely normal. However, if the displacement of the femur is of sufficient magnitude, aseptic necrosis of the head may result. When the patient is not forewarned of the possibility of late pain in the hip and continues to bear weight on the extremity after the return of symptoms, the head may undergo collapse with depression of the articular surface. These changes are at times irreparable and result from compression of dead trabeculae. Whenever possible, the extremity should be protected from weight bearing by means of crutches for four to six months after the postreduction period of immobilization. If roentgen evidence of aseptic necrosis of the head is not present at this time, the patient may resume full weight bearing with the likelihood that the head will remain alive, although roentgenographic follow-ups should continue for an additional twelve months. If, however, the head becomes necrotic early, protection can be provided and continued until serial roentgenograms show final revascularization and replacement by new bone. In young children aseptic necrosis following a dislocation of the hip appears somewhat similar to that observed in Legg-Perthes disease, and the immediate end results are equally satisfactory. When the femoral head in older children becomes necrotic, pathologic alterations simulate those seen in adults, and the results are equally poor. This appears to be true whether the primary pathologic condition was a traumatic dislocation, a fracture of the neck of the femur or a slipping of the upper femoral epiphysis.

Arthroplasty of the Hip Joint.—Albee and Preston [574] review some of the difficulties associated with arthroplasty of the hip with the use of the vitallium cup. They believe that vitallium cannot resist infection

573. Banks, S. W.: Aseptic Necrosis of Femoral Head Following Traumatic Dislocation of Hip: Report of Nine Cases, J. Bone & Joint Surg. **23**:753-781 (Oct.) 1941.

574. Albee, F. H., and Preston, R. L.: New Vitallium Cup for Arthroplasty of Hip, J. Internat. Coll. Surgeons **4**:289-293 (Aug.) 1941.

as well as autogenous membranes, although it does possess such characteristics as indestructability, compatability with living tissues and resistance to body fluids. They feel that the design of the cups hitherto employed is faulty in that there is no inhibition of the proliferation of new bone or osteophytes about their margins. This may result in the recurrence of ankylosis or a bony blockage to free motion. The second criticism offered is that the cup by virtue of its rounded contour capsizes as soon as pressure is brought to bear on its edges, particularly if laxity of the abductor muscles is present. This laxity usually results from too short a kinesiologic lever.

The cup described by the authors is so made as to conform to the rim of a normal acetabulum, and the flanges are adapted to fit completely over its rim. A bolt fixes the flanges to the region of the anteroinferior spine of the ilium, anchoring the cup so that there is no possibility of its being displaced or capsizing. These flanges also completely inhibit the possibility of a sleeve of bone forming about the acetabulum or the neck of the femur, and in this way reankylosis is prevented. Albee and Preston have also developed new reamers which may be inserted into the hip joint with the handle clamped on at any point around the periphery. This permits accurate shaping of the head and the acetabulum without the necessity of dislocating the hip.

The authors also feel that the results are poor in a large group of cases because of a shortening of the kinesiologic lever. If this condition is present, it should be lengthened either at the time of the arthroplasty or at a later date.

Toumey [575] prefers the vitallium cup arthroplasty to other operative procedures and conservative treatment for malum coxae senilis. After the operation adhesive traction is applied, and gentle active and passive motion is begun almost immediately. Four weeks after the operation patients are allowed to walk with the aid of crutches and exercise on a stationary bicycle. If adduction contracture is present, tenotomy is performed either at the time of the major procedure or about one week later.

Since July 1939, 22 vitallium cup arthroplasties have been performed at the Lahey Clinic, Boston. The results were good in 16 cases and fair in 2. The condition was unchanged in 3 cases, and the result was poor in 1 case of rheumatoid arthritis with an ankylosed hip on the opposite side.

[ED. NOTE: We believe that correction of deformity, particularly of an adduction deformity, is of great importance as a preliminary step to arthroplasty of the hip joint.]

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575. Toumey, J. W.: Surgery of Arthritis of Hip and Knee, S. Clin. North America **21**:895-901 (June) 1941.

Cole [576] has had occasion to examine 2 femoral heads and microscopic sections from them after a vitallium cup arthroplasty. In the first case the patient had been walking for nearly six months, and replacement of a defective cup was necessary. In the second case no weight bearing and little motion had taken place on account of the condition of the patient, who died one month after operation. In neither of these did the author find the cartilage mentioned by Smith-Petersen, and it is probable that its development depends on longer use of the hip, as one of the latter's two specimens was twenty-one months postoperative and the other twenty-five months. In the first case on removal of the cup a beautifully shaped smooth bluish surface was exposed which appeared to be cartilaginous but which was covered by a thin membrane extending to it from the capsule. Similar findings were present on the surface of the acetabulum. A block of bone removed from the center of the head and examined microscopically showed no cartilage but merely a thin fibrous layer over compact bone. In the second case the cup was still loose, and the stump of the neck was rounded and smooth with irregular islands of what appeared to be cartilage scattered over its surface. Histologically, however, no cartilage was found, and the surface was covered with organizing fibrous tissue.

The postoperative treatment for this procedure is carefully outlined by the writer.

Reconstructive Operations.—Albee [577] reports that in partial paralysis of the muscles about the hip joint the kinesiologic lever, i. e. the lever formed by the head, the neck and the greater trochanter, is of great importance. It is identical in mechanical principle with that of the olecranon process. The pathologic condition, the weight-bearing stability and the function of the hip joint are markedly influenced by the balance between the length of this lever and the strength of the muscles pulling on it. In cases of infantile paralysis the lever is often not of normal physiologic length because of the weakening of the attached trochanteric muscles. To increase the power of flexion and abduction this lever should be lengthened laterally and anteriorly. In cases in which there is weakened extension and abduction, the lever should be lengthened laterally and posteriorly.

A strong shell of bone from the superolateral surface of the greater trochanter about 4½ inches (11.4 cm.) in length, 1½ inches (3.8 cm.) wide and ⅝ inch (1.6 cm.) thick with the muscular insertions undisturbed is turned outward and held in that position by a bone graft of adequate dimension. In addition to infantile paralysis, shortening of the neck of

576. Cole, W. H.: Use of Vitallium in Surgery with Special Reference to Cup Arthroplasty, Proc. Roy. Soc. Med. **34**:779-782 (Oct.) 1941.

577. Albee, F. H.: Surgical Elongation of Kinesiologic Hip Lever in Partial Paralysis, J. Internat. Coll. Surgeons **3**:512-516 (Dec.) 1940.

the femur caused by destructive lesions or by arthroplasty may be an indication for this operation. In the author's experience excellent results have been obtained in such cases.

The operative technic is described in detail. After the operation immobilization is maintained in a double hip spica cast in moderate abduction for four weeks.

Milch [578] has again emphasized the causes of poor results of osteotomies of the Lorenz type. He finds that paradoxically the roentgenographically satisfactory bifurcations almost invariably result in marked disability of a definite type.

Pain was present in varying degree. In some cases the pain was so mild that it was overlooked in the satisfaction at the restoration of stability. In others it was so severe that the patients insisted on relief. There was always an annoying increase in the intercrural distance with an inability to bring the legs into parallel position. The patients could not completely flex or adduct the thighs. In the seated position they could not cross their legs tailor fashion. They could not assume the squatting position and had difficulty in putting on their shoes and stockings. In the erect position they stood with the legs abducted and the feet everted. Forward progress was possible only with a peculiar twisting and waddling gait, despite the fact that the Trendelenburg sign was usually absent.

On the other hand (and notably in children), it was observed that as the prong of the shaft fragment disappeared in the roentgenograms the pain and the disability vanished, usually without loss of the stability.

Such marked improvement, invariably observed in children following absorption of the bony prong, suggested that in adults in whom disability persisted similar relief might be obtained by surgical amputation of the offending spike of bone.

Milch has studied the action of the spike of bone on the skeleton. The external ischial border together with the posterior rim of the acetabulum forms a ridge which, except for the flare of the ilium, presents the most lateral projection of the pelvis. It is apparent, therefore, that when the osteotomized shaft makes contact with the pelvis at any point other than along this ridge the point of contact must lie medial to the ridge and must lead to interference with rotation when the femoral head is fixed.

The head of the femur was dislocated posteriorly onto the ileum, and the experiments were repeated. Essentially with one exception the same results were obtained. When the osteotomized shaft was displaced into the acetabulum according to the described technic of the

578. Milch, H.: "Pelvic Support" Osteotomy, J. Bone & Joint Surg. **23**:581-595 (July) 1941.

operations, the most marked limitation in all arcs of motion was obtained. This was immediately recognized as being caused by the steeply sloping walls of the acetabular cavity, which, like the ridge, acted to obstruct the motion of the spike. This observation is of especial significance, because of the expressed opinion that "the osteotomy is merely the preparatory step in the bifurcation operation. The essential act is the reposition of the distal fragment into the acetabulum." On the contrary, it was found that in the presence of a femoral head and neck the acetabular position of the distal fragment was the worst of all the sites of pelvic abutment and that the consequent limitation of motion could be overcome only by resection of the spike. However, when the femoral head and neck were amputated, the acetabular position of the fragment acted to restore good balance and stability without limitation of motion. Though this outcome could have been predicted from the principle that simultaneous universal motion about each of two separate point fulcrums is impossible in three dimensional space, the studies have demonstrated conclusively that the acetabular position of the bifurcation spike is to be avoided except in treating those conditions in which the instability results from a pathologic loss of the head and the neck.

In accordance with these findings the author has found that resection of the projecting spike of the shaft fragment eliminates the second point of pelvic abutment, that motion is restored and that the pain is relieved without loss of stability.

The author has noted also that excessive pelvic tilt is present in unilateral cases when excessive abduction of the distal fragment is found. In his opinion this could be overcome by making sure that the angle between the shaft and a line connecting the femoral head to the upper end of the distal fragment was not more than the angle of normal inclination of the outer wall of the level pelvis.

The therapeutic implications of these considerations are obvious. Care should be taken to avoid the production of a projecting spike at the site of osteotomy or resection of this prominence should be done if it has formed. The osteotomy should be carefully planned in order to avoid a postosteotomy angle which is in excess of the angle of normal pelvic inclination (210 to 230 degrees). The author feels that a revision of old osteotomies is indicated if either of these factors is found to be interfering with good function.

[ED NOTE: This article is of a highly technical character, and we suggest that it be read in detail by those who are interested in the bifurcation operation.]

Subtrochanteric Osteotomy.—Franck and Kiaer[579] report on the reexamination of 43 patients with old congenital dislocation of the hips

579. Franck, S., and Kiaer, S.: Palliative Subtrochanteric Osteotomy, Acta orthop. Scandinav. **11**:153-171, 1940.

who were treated by palliative subtrochanteric osteotomy during the period 1926 to 1935. In the authors' opinion the indications for this operation are subjective and objective symptoms. The subjective symptoms are pain and fatigue in and around the hip joint and in the lumbar region, the pain being aggravated by lifting. The objective signs are those resulting from impairment of the stability of the hip joint, such as waddling gait, the Duchenne-Trendelenburg symptom and increased lordosis.

Prior to operation 37 patients had both subjective and objective symptoms. Two patients were operated on because of subjective symptoms alone. Four patients had only objective findings. In all of the cases complete congenital dislocation of the hip was presented, and in 5 cases there was neoarthrosis. A total of 43 patients were treated with fifty-three osteotomies, a bilateral operation being performed in 10 cases. In the total estimation of the therapeutic results there were 27 bifurcation osteotomies of the Lorenz-Bayer type. Twenty-three were supporting osteotomies of the Drehmann type. Three Schanz osteotomies were performed, but these cases were not included in the evaluation of end results. In both the bifurcation and the supporting type of osteotomy the operation was done at the level of the acetabulum so that the osteotomy angle fell outside the socket. In all cases in which there was lordosis, an attempt was made to turn the osteotomy in the sagittal plane with the angle opening posteriorly. In evaluating the end results shortening was left out of consideration because the result was estimated after counterbalancing with corrective footwear. The average shortening resulting from the operation was about 2 cm. Of 21 patients treated with bifurcation osteotomy, 10 had excellent results; 6 had good results; 1 had a fairly good result, and 4 patients were unchanged. Of the 20 patients who were treated with the supporting osteotomy of Drehmann, 9 had excellent results; 4 had good results; 3 had fairly good results, and 4 were unchanged. The only difference noted between the results of the supporting and the bifurcation osteotomy was that after the bifurcation osteotomy the mobility of the hip joint was more impaired than after the supporting osteotomy although not to such an extent as to shift the clinical judgment of the results.

The authors have also attempted to correlate the end results with regard to the angle obtained by the osteotomy both in the frontal and in the sagittal plane. In regard to the osteotomy angle in the frontal plane two factors are of significance in relation to the stability of the hip: the placing of the axis of the lower extremity as near as possible to the midline and the tension of the gluteal muscles. Both of these requirements are met through the valgus position of the osteotomy. Franck and Kiaer point out that in children under the age of 16, the

osteotomy angle in the frontal plane should be one of marked valgus, about 130 degrees, to allow for self straightening of the osteotomy angle as growth progresses. They find that in the great majority of cases the Trendelenburg phenomenon is abolished or greatly improved when the frontal angle of the osteotomy is between 140 and 160 degrees. They note with particular interest that in 3 cases the Trendelenburg phenomenon was abolished even though the frontal angle was lacking. This occurred presumably because a good angle was present in the sagittal plane, thus pulling the trochanter sufficiently downward so that the tension of the gluteus medius muscle was improved. Of 7 patients on whom unilateral osteotomy was performed with a sagittal angle of 170 to 140 degrees, 6 showed improvement in their lordosis. In the seventh, however, lordosis was unchanged. In 11 cases in which there was no angle in the sagittal plane, the lordosis remained unchanged. In 6 cases of bilateral osteotomy with a sagittal angle of 170 degrees, there was severe lordosis present prior to the operation. On reexamination of the patients only slight or normal lordosis was demonstrated. In 7 cases with a good osteotomy angle in the frontal plane but with no osteotomy angle in the sagittal plane, there was no change in the lordosis. The authors feel that these findings justify the claim that the osteotomy angle in the sagittal plane is of significance to the correction of the lordosis.

The writers believe that the success of the operation depends on the adducted position of the proximal fragment above the osteotomy and on the downward turning of the trochanter, whether it be in the frontal, the sagittal or the intermediate plane, since this is the important factor in activating the gluteal musculature. The authors lay particular stress on the angle in the sagittal plane or the intermediate plane. They feel that an expedient angle in this direction is sufficient to activate the musculature of the buttocks and at the same time change the static conditions so that the lordosis is straightened out. If the upper displacement of the trochanter is so great that it does not seem likely that turning down of the trochanter will be sufficient to activate the gluteal musculature, this might be accomplished by moving the trochanter out after the method of Lexer or Albee.

Miscellaneous.—Plantenga [580] discusses the differential diagnosis of disease of the hip joint, especially in children, describing several cases of coxitis fugax which he defines as a nonspecific inflammation of the synovial membrane of obscure causation. This diagnosis may be arrived at only after ruling out such conditions as tuberculosis, osteomyelitis, and Legg-Perthes disease. Clinically, a history of heavy strain or exercise is found. The patient tends to keep the hip and the knee flexed and in slight external rotation. Swelling and pain on pressure over the hip

580. Plantenga, B. P. B.: Coxitis Fugax, Geneesk. gids **19**:296-302 (April 18) 1941.

joint are present. Roentgen findings are normal. The cause may be toxic, traumatic or infectious-allergic. Some patients are cured after a few days' rest in bed. In others the condition may persist for a longer time and may require traction. The condition is more common than is supposed and is of importance because it has a good prognosis and should be differentiated from more serious conditions.

Delitala [581] presents a roentgen cinematographic study of the hip joint. In a patient with ankylosis of the hip motion takes place in a frontal plane through the lumbosacral articulation and through the normal joint. This combined motion in walking amounts to about 25 degrees, which is approximately the same as that occurring in a normal hip joint. The Roser-Nélaton line may be used as a standard to judge flexion angulation in patients with ankylosis. A favorable position would be an angle of 50 degrees to this line. A greater angle is good for standing but not for walking. Ankylosis in adduction, abduction, internal or external rotation is unfavorable and should be corrected.

Schein and Lehmann [582] review the literature regarding acute trochanteric bursitis with calcification and report on the findings in 7 cases. Four patients had complained of pain in the region previous to their illness on admission. Two had calcific subacromial bursitis before or after the trochanteric involvement. The presenting symptoms were remarkably constant, i. e. severe pain in the hip region with inability to walk and with an onset usually less than forty-eight hours before examination. The outstanding physical findings were exquisite localized tenderness over the greater trochanter, severe on abduction and rotation of the hip with little or no pain on flexion and no tenderness over the hip joint proper. Roentgen examination showed calcification in all cases, but the density, the configuration and the position of the shadows varied. The total course of disability was about three days. The treatment consisted of rest in bed, the application of cold or hot compresses or local infiltration with procaine hydrochloride. In 4 cases in which the follow-up was from nine months to one year, there was no recurrence. Disappearance of the calcification was demonstrated by roentgenograms in 2 cases after one month. The pathogenesis of this lesion is similar to that of calcified bursitis about the shoulder. Clinical healing of the condition is associated with hyperemia, the increased vascularity causing absorption of the calcified deposit.

Francon [583] reports a single case of ischial bursitis with pain on coughing, sitting or walking over long distances. The pain was increased

581. Delitala, F.: Deambulation in Ankylosis: Contribution to Articular Physiopathology, Chir. d. org. di movimento **26**:5-13 (July) 1940.

582. Schein, A. J., and Lehmann, O.: Acute Trochanteric Bursitis with Calcification, Surgery **9**:771-779 (May) 1941.

583. Francon, F.: Local Use of Procaine and Procaine Compounds in Therapy of Ischiatic Bursitis, J. de méd. de Lyon **22**:15-16 (Jan. 5) 1941.

by slight adduction and internal rotation of the thigh. Repeated injections of procaine hydrochloride into the tender area over the ischial tuberosity gave complete relief of symptoms.

Blixenkrone-Moller [584] has used extrapelvic resection of the obturator nerve in several cases of osteoarthritis of the hip joint. Of 6 patients with adduction contractures, 5 showed improvement while 1 was unimproved. In 3 cases without adduction contractures there was no improvement. There seemed to be no relation between the degree of arthritis and the relief obtained from this procedure. The author feels that Camitz is correct in his view that the pain in disease of the hip is due to spasticity of the adductor muscles, but only in those cases presenting an adduction contracture.

In 7 cases of secondary arthritis deformans only 1 patient secured relief from pain; this was the patient with bilateral dislocation of the hip. In certain cases resection of the obturator nerve is not adequate to relieve pain. Roentgen therapy should be kept in mind as it may render some of these patients free from pain.

XV. CONDITIONS INVOLVING THE KNEE JOINT

Function and Mechanics.—Brantigan and Voshell,[585] after a study of approximately 100 knee joints, many of which were in the fresh condition, have clarified many questions as to the functions of the ligaments and the meniscuses of the knee joint. They have found that lateral and rotary motions of the knee joint in extension are controlled by the capsule, the collateral ligaments and the cruciate ligaments and that in flexion they are controlled by the same structures except for the fibular collateral ligament.

Forward gliding of the tibia on the femur is controlled by the anterior cruciate ligament, whereas backward gliding is controlled by the posterior cruciate ligament. Lateral gliding of the tibia on the femur is controlled by the tibial intercondyloid eminence and the femoral condyles with the aid of all the ligaments. Hyperextension is controlled by both collateral ligaments, both cruciate ligaments, both meniscuses, the posterior aspect of the articular capsule, the oblique popliteal ligament and the structure of the femoral condyles.

Hyperflexion is controlled by both cruciate ligaments, both meniscuses, the femoral attachment of the posterior aspect of the capsule, the femoral attachment of both heads of the gastrocnemius muscle and the osseous structure of the condyles of the femur and the tibia.

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584. Blixenkrone-Moller, N.: Treatment of Arthritis Deformans of the Hip by Resection of the Obturator Nerve, Acta orthop. Scandinav. **11**:11-30, 1940.

585. Brantigan, O. C., and Voshell, A. F.: Mechanics of Ligaments and Menisci of the Knee Joint, J. Bone & Joint Surg. **23**:44-66 (Jan.) 1941.

The meniscuses cushion hyperextension and hyperflexion. Although the medial meniscus and the tibial collateral ligament are closely related, there is no strong fibrous tissue attachment between them. Also, this ligament glides forward and backward in extension and flexion, and some portion of it is always taut. The capsule of the joint is in the most relaxed position when 15 to 30 degrees of flexion is obtained. The medial femoral condyle acts more nearly as the axis of rotation of the knee joint.

If the anterior cruciate ligament and the tibial collateral ligament are ruptured, both probably should be repaired, although repair of either alone usually gives a satisfactory functioning knee joint.

[ED. NOTE: This article represents an important contribution to orthopedic surgery.]

Function and Structure.—Kostler [586] is of the opinion that the joint fluid and lymph are not sufficient to nourish the meniscuses. The blood supply plays an important part. The results of his experiments with animals support the work of Gebhardt in that Kostler found that bionecrosis may take place if the blood supply to the meniscuses is damaged. He concludes that damaged softened meniscuses should be left in the knee only if they contain living healthy blood vessels. [ED. NOTE: The importance of degenerative changes in semilunar cartilages has been underemphasized.]

Wounds and Injuries.—Speaking from experience gained in the first World War and in the evacuation of Dunkirk, Ogilvie [587] writes that immobilization of any injury of the knee from the earliest moment until infection has been averted or overcome is the key to success. The value of the treatment of injuries of the knee with sulfanilamide is acknowledged.

Most wounds seen within six hours should be debrided, packed with sulfanilamide (dry or mixed with petrolatum) and then immobilized in a plaster spica cast. The synovial cavity may be closed with the finest of catgut but not the capsule. The sutures in the skin should be placed loosely. If evacuation of the patient becomes imperative, the surface sutures should always be removed first, regardless of the condition of the wound. If serious damage to the blood vessels and the nerves is present, amputation should not be delayed.

If the wound is seen within six to twenty-four hours after infliction, some of it still can be debrided. Immobilization and sufanilamide therapy usually are continued, and the wound should be watched care-

586. Kostler, J.: Trophic Disorders of Meniscus: Experimental Study, Arch. f. klin. Chir. **199**:49-61, 1940.

587. Ogilvie, W. H.: Wounds of Knee Joint, Lancet **1**:471-473 (April 12) 1941.

fully for signs of sepsis. The battle for a septic knee is usually decided within four days. If sepsis is present, the knee should be drained, and immobilization should be continued. If the patient is not better at the end of four days, it is usually better to amputate.

Palmer [588] briefly discusses injuries of the knee joint sustained in football. These may cause acute or chronic inflammation of any of the thirteen bursas about the knee, but those most commonly affected are the ones on the front and the outer side. Infection of these bursas may result from penetrating wounds and metastatic infections. Other common conditions resulting from trauma are: (1) acute synovitis due usually to injury over the internal femoral condyle; (2) tearing of the capsule with or without rupture of the internal lateral ligament; (3) injury to the internal semilunar cartilage, and (4) Baker's cysts. Palmer states that the injection of 2 to 5 drops of tincture of iodine when the internal semilunar cartilage is loose only in the central portion often will produce enough adhesions to fix the cartilage firmly to the capsule.

Leger and Delinotte [589] advocate early repair of tears of the lateral ligaments. They report 4 cases of severe strain of the knee with tear of the internal ligament and 1 of tear of the external lateral ligament. The 5 patients were operated on within a week to a month after injury. In 2 cases of repair of the internal lateral ligament, the ligament was reinforced by plication of the capsule. In 1 case of tear of the external lateral ligament, the ligament was reinforced with the biceps femoris tendon. It was too soon at the time the authors wrote for final analysis of the results, but they apparently will be better than would have been achieved by conservative means.

LeRoy,[590] in reporting cases of recent traumatic hemarthrosis, advocates aspiration of blood from the knee and injection of 10 cc. of a 1 per cent solution of procaine hydrochloride. [ED. NOTE: These radical views on the treatment of acute ligamentous tears about the knee are perhaps worthy of notice.] He reports 9 cases in which this treatment was used: Satisfactory results were achieved in 7 cases after one injection and in 2 cases after two injections.

Wounds and Injuries of the Knees.—Evans,[591] who has had extensive experience with injuries of the knee among athletes at the University of

588. Palmer, D. H.: Football Injuries to Knee Joint, Northwest med. **40**: 143-145 (April) 1941.

589. Leger and Delinotte: Grave Sprain of the Knee: Four Cases, Mém. Acad. de chir. **66**:861-868 (Nov. 27-Dec. 11) 1940.

590. LeRoy, A.: Therapy of Recent Traumatic Hemarthrosis of the Knee, Mém. Acad. de chir. **66**:648-652 (Oct. 16-30) 1940.

591. Evans, E. T.: Internal Derangement of the Knee in the Athlete, Bull. Minnesota M. Found. **3**:11 (Nov.) 1941.

Minnesota, classifies such injuries as: (1) simple sprains with effusion; (2) torn lateral ligaments; (3) torn crucial ligaments; (4) torn semilunar cartilages, and (5) recurrent disability from old injury. His treatment of torn semilunar cartilages consists of the application of cold packs, aspiration, traction (rather than manipulation) to unlock and then operation.

The treatment of war wounds of the knee has been reviewed by Fisher.[592] He emphasizes the seriousness of wounds of joints and the need for prompt care of them. The following principles of treatment are laid down: 1. Treat promptly. 2. Treat shock. 3. Make roentgenograms. 4. Use aseptic technic. 5. Give sulfanilamide orally and locally.

A suitable knee brace has always been hard to find. Jordan[593] introduces one made of woven elastic, reinforced in front with leather straps and containing a vertical piece of spring steel posteriorly which has a piano hinge at the popliteal fossa. It is stated that this brace allows flexion but at the same time increases lateral stability.

An interesting case of irreducible lateral dislocation of the patella with rotation, so that the articular surface was turned away from the femoral condyle, is reported by Inman and Smart.[594] Open reduction was necessary; at the same time the torn tendons also were repaired.

Rupture of the Tendon of the Quadriceps Femoris Muscle.—Martin[595] emphasizes that the treatment of rupture of the tendon of the quadriceps femoris muscle is surgical unless the rupture is unmistakably incomplete and exhibits signs of prompt healing. Stainless steel wire usually is preferred as the means by which the tendon is approximated to the patella.

In old injuries the scar tissue is not resected but is divided and dissected upward to the tendon so that the scar tissue forms a strap or apron with which to pull down the retracted tendon. After the tendon has been sutured to the patella, this apron of scar tissue is sutured over the anterior aspect of the patella. Sometimes, if the sutures of silk or wire are under undue tension, they can be reinforced with fascial bands. After surgical repair, functional stimulation by means of guarded use of the joint should be permitted as early as safety permits to combat muscular atrophy.

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592. Fisher, A. G. T.: Treatment of War Wounds of Knee Joint, M. Press **205**:454-457 (June 4) 1941.

593. Jordan, H. H.: New Elastic Knee Brace with Posterior Hinge, M. Rec. **153**:87-88 (Feb. 5) 1941.

594. Inman, V. T., and Smart, B. W.: Irreducible Lateral Dislocation of Patella with Rotation: Case, J. Bone & Surg. **23**:695-700 (July) 1941.

595. Martin, J. W.: Rupture of Quadriceps Femoris Tendon, Nebraska M. J. **26**:11-12 (Jan.) 1941.

Arthrodesis.—Hellstadius [596] points out that acceleration of the consolidation and consequent shortening of the immobilization time can be obtained by compression of the resectioned ends of bone against each other. This also lowers the risk of formation of pseudarthrosis. The author describes a quadrangular metal frame one side of which is movable with a vertical supporter in each of the four corners. These supporters can be fastened to Kirschner wires which have been passed through the bone ends above and below the resected knee joint. By means of a screw the movable side of the frame with its vertical supporters can be approximated to the opposite side, and through the resulting pull on the Kirschner wires the resectional surfaces can be brought into close approximation and even compression. The apparatus is recommended especially for use at the ankle and also at the astragalocalcaneal joint, but in these instances the proximal pair of supporters take hold of the Kirschner wire at the upper end of the tibia, while the other pair of supporters are fastened into heavy loops of cord which are incorporated in the plaster of the leg. The usual type of plaster of paris cast is always applied, but windows are cut in the plaster around the Kirschner wires when arthrodesis of the knee is to be done, while the cast does not extend to the Kirschner wire when arthrodesis of the joints below the knee is to be done. [ED. NOTE: Such a piece of apparatus deserves more widespread trial.]

Dercum's Disease.—McGavack and Klotz [597] report a case of juxta-articular adiposis dolorosa (Dercum's disease) in which there were unusual neurologic phenomena. Impairment of joint function was omnipresent in this case, as well as in more than 500 cases reported. Inability to control the legs or to bear weight on them is far from rare. The authors state that it is logical to accept adiposity, asthenia, pain, psychic disturbances and neurologic manifestations as the outstanding phenomena in Dercum's disease, that each may be present in varying degree and that superimposed on them may be secondary conditions, such as hypochromic anemia, certain types of arthropathy and the like.

In the case presented symptoms were confined mainly to the lower extremities. Roentgenograms of the patient, a 63 year old white woman, disclosed osteoarthritis of the knee joints, muscular atrophy and an increase in subcutaneous tissue throughout the lower extremity.

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596. Hellstadius, A.: Apparatus for Firm Apposition of Resectional Surfaces of the Knee in Intra-Articular Arthrodesis, Acta orthop. Scandinav. **11**:190-198, 1940.

597. McGavack, T. H., and Klotz, S.: Juxta-Articular Dercum's Disease: Case Report, New York M. Coll. & Flower Hosp. Bull. **3**:299-305 (Dec.) 1940.

Baker's Cyst.—In a reprint of Baker's [598] second communication concerning the formation of synovial cysts first published in 1885 it is concluded that abnormal synovial cysts may be formed in communication not only with the knee but also with the shoulder, the elbow, the wrist, the hip and the ankle joints. He warns that direct communication between the joint and the abnormal synovial cyst frequently is deceptive and should not lead to the inference that no such communication exists. [ED. NOTE: The conditions which are now classified as synovial cysts arising from joints, ganglions and bursas are not distinguished separately by Baker, and he apparently is of the opinion that all arise from distention of the synovia of the joint. In some of the cases reported in which the condition has arisen in locations other than the knee, it seems in accord with present knowledge to represent bursal inflammation, and 1 patient referred to by Baker but observed by another author probably had tuberculous tenosynovitis.] Baker states his suspicion that in some cases a relation to osteoarthritis existed and that in others there was a relation to the condition which would now be called tabetic arthropathy or Charcot's joint.

Osgood-Schlatter Disease.—Jentzer and Perrot [599] discuss the causation of Osgood-Schlatter disease and present the results of pathologic studies made in 4 cases. Definite conclusions could not be drawn, but they believe that a predisposing factor is present in all cases. They advocate excision of the tubercle and believe the period of disability is shortened by this procedure.

Synovectomy.—Ghormley and Cameron [600] report on 103 knee joints operated on at the Mayo Clinic, Rochester, Minn., in which synovectomy was performed. They state that the best indications for the operation are: (1) traumatic arthritis; (2) synovial osteochondromatosis, and (3) xanthoma or benign tumors. The next best indications for synovectomy are: (1) chronic infectious arthritis; (2) chronic synovitis, and (3) intermittent hydrarthrosis. These indications are much in accord with those for synovectomy reported by Magnusson.[601] He states that the best indication is nonspecific inflammation of the synovia; this probably is the classification group in which traumatic arthritis, as listed just previously, would be placed. He reports the performance of synovectomy ten times for 9 patients with good results.

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598. Baker, W. M.: Baker's Cyst: Formation of Abnormal Synovial Cysts in Connection with Joints, M. Classics **5**:805-820 (May) 1941.

599. Jentzer, A., and Perrot, A.: Osgood-Schlatter's Disease, Helvet. med. acta **8**:162-174 (April) 1941.

600. Ghormley, R. K., and Cameron, D. M.: End-Results of Synovectomy of Knee Joint, Am. J. Surg. **53**:455-459 (Sept.) 1941.

601. Magnusson, R.: Total Synovectomy of Knee Joint, Acta orthop. Scandinav. **11**:235-263, 1940.

Meniscuses.—In a ten-year review of internal derangements of the knee, Cave and Staples [602] have found that congenital anomaly of the meniscuses occurred in 2.4 per cent of the cases. They review the symptoms and signs and emphasize the point that the lateral meniscus normally is the one involved. Treatment is by surgical excision, whether the meniscus is damaged or not.

Gallagher [603] reviews the method he employs in the preoperative and postoperative care of fractured semilunar cartilages. He stresses two points: first, that only half of the cartilage should be removed at a time; and second, that routine dressings should be applied twenty-four and forty-eight hours postoperatively with aspiration of the contents of the joint if any excess fluid is present. The average time before his patients are allowed to return to work is seven weeks.

Osteochondromatosis.—Wilmoth [604] reports the results of a follow-up study made in 10 cases of osteochondromatosis involving the knee, the elbow or the hip joint. In none of the cases in which surgical removal of the loose bodies was carried out was there any tendency toward the formation of new loose bodies. The longest period for which any of the patients were followed after operation was four years. In the knee joint the loose bodies occurred fairly constantly in the posterior compartment. If the loose bodies were confined to this space, the synovial membrane there was thickened, but the rest of the synovial membrane was normal. When the bodies occurred throughout the joint, all the synovial membrane was thickened. The symptoms noted were those of arthritis rather than any sudden pain, and when loose bodies were present, excision of them always was advised. Synovectomy was done when the synovial membrane was found to be thickened.

(To Be Concluded)

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602. Cave, E. F., and Staples, O. S.: Congenital Discoid Meniscus: Cause of Internal Derangement of Knee, Am. J. Surg. **54**:371-376 (Nov.) 1941.

603. Gallagher, C. A.: Our Method of Care of Fractured Knee Cartilages, J. Oklahoma M. A. **34**:237-239 (June) 1941.

604. Wilmoth, C. L.: Osteochondromatosis, J. Bone & Joint Surg. **23**:367-374 (April) 1941.

REVIEW OF UROLOGIC SURGERY

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KIDNEY

Crush Syndrome and the Kidney.—A number of timely and exceptionally important articles dealing with the effect on the kidney of trauma to other parts of the body have recently appeared.

Bywaters[1] states that in a typical case in which the patient is severely injured and has a history of, for instance, being buried for several hours with masonry resting across a limb, such a patient will be shocked on admission or soon after, with a decrease in blood pressure which follows a preliminary period of apparent well-being. During this initial phase hemoconcentration occurs (and compensatory vasoconstriction) because of loss of plasma into the injured part, which becomes swollen and hard. There is also loss of sensation and power; the skin shows whealing and, later, blisters. Arterial pulsation distally may be impaired. After restoration of blood volume by the transfusion of blood or serum the patient recovers, but it is noticed that the urine is blood stained and contains albumin and pigmented granular casts. During the next few days the urinary output decreases and the urine becomes

1. Bywaters, E. G. L., in Discussion on the Effects on the Kidney of Trauma to Parts Other Than the Urinary Tract, Including Crush Syndrome, Proc. Roy Soc. Med. **35**:321-328 (March) 1942.

clearer; the blood pressure increases to a high value; there is a progressive increase in blood urea, phosphate and potassium and a decrease in alkali reserve. The patient becomes alternately drowsy and apprehensive; death occurs suddenly on about the seventh day and is occasionally preceded by abnormalities of cardiac action similar to those produced experimentally by intoxication with potassium.

If death does not occur before the usual time from some other cause, the kidneys are swollen and wet. The most obvious feature microscopically is the presence of pigment casts in the collecting tubules similar to those seen in the urine. More important, Bywaters believes, are the severe tubular damage seen in the distal convoluted tubules and Henle's loop of the boundary zone—often with complete necrosis—and the discharge of hyaline casts into the interstitial tissue and surrounding cellular reaction. This corresponds to the biochemical indication of tubular dysfunction and leakage.

The critical period is reached toward the end of the first week; most patients who survive to the eighth or ninth day will recover. The surviving patients (who amount to about a third of the patients in the total number of collected cases) have been in general less severely injured than those who died. The severity of the injury must be judged by the amount of tissue rendered necrotic, hence (when the circulation has been reestablished) by the amount of hemoconcentration produced by loss of plasma into the damaged zone. The severity of the renal lesion must be judged by the increase in blood urea and blood pressure, by the urinary output and by tubular function as measured by the percentile concentration of urinary urea as compared with that in the blood. A good prognosis may be given for the patient who has inextensive injuries, and a relatively good one is associated with injuries so severe that there is no reestablishment of the circulation to the part. A good prognosis may be given if the patient has a decreasing value for blood urea or, since there is a progressive increase in most cases in which the outcome is fatal, a value for blood urea less than the value that would be expected for the time after injury. In cases in which injury is fatal, the curve for the concentration of blood urea rises steadily until death supervenes on or about the seventh day. Concentration among surviving patients may describe such a curve and then decrease, or it may fail to increase as much and may decrease earlier. The decrease is associated with diuresis. At the same time hypertension disappears. Persons rescued from collapsed houses usually have been treated first for shock; then the circulation to the injured limb has been reestablished, and the kidneys have not been considered until the fourth day after injury; but if instead of this procedure such patients had been treated first of all for renal failure and then given the benefit of establishment of good alkaline

diuresis as soon and as rapidly as possible, followed by, finally, treatment of shock and local lesion, the mortality rates would have been lowered, Bywaters believes.

Belsey [2] discusses the effects on the kidney of trauma to parts other than the urinary tract, and he includes the crush syndrome in his remarks.

In the crushed limb the following changes have been observed: First, necrosis of muscle, patchy in distribution and rarely corresponding to portions of damaged overlying skin, such as would suggest that the necrosis is caused by direct pressure. The muscle is pale and mottled. Hemorrhage into the muscle or the tissue planes is not constant. There are edema of the limb and an increase of tension in the tissues within the fascial compartments of the limb. During life evidence of impairment of peripheral circulation and sometimes of absence of pulsation is found, but at necropsy there is rarely evidence of thrombosis or gross damage to the main arteries of the limb, although in a few instances rupture of a major vessel has been found.

Loss of neural function has been recorded in the majority of cases and has commonly involved all the nerves of the limb, a distribution suggesting that the failure of conduction is caused by ischemia and asphyxia rather than by direct pressure. Among patients who have survived, the recovery of neural function has been steadily progressive for six to twelve weeks and usually has been complete.

In the future, Belsey states, there must be more control of and attention to the time factor. It is now known that spontaneous recovery can occur, and difficulty arises from the fact that treatment to be of any avail probably will have to be started early, before it becomes obvious on the basis of the rapidly diminishing output of urine that the patient is a member of that group in which death inevitably occurs between the sixth and the ninth day with complete anuria.

Little in the way of operative treatment has been employed as yet, and probably rightly. Belsey says that primary amputation has been performed in 3 cases, in 2 of which death occurred. In the first case, in which the patient was a girl 17 years old whose left leg had been crushed for nine hours, amputation was performed through the thigh and apparently above the level of tissue damage. This was carried out at the thirty-sixth hour after the injury, because of incipient gangrene of the limb. There was no evidence of damage to other limbs. Death occurred on the sixth day, in the presence of almost complete suppression of urine.

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2. Belsey, R., in Discussion on the Effects on the Kidney of Trauma to Parts Other Than the Urinary Tract, Including Crush Syndrome, Proc. Roy. Soc. Med. **35**:328-332 (March) 1942.

Decompression of the limb by incision into the deep fascia has been done in 7 cases, of which only 3 have been recorded so far. Three patients died and 4 survived.

Decapsulation of the kidneys was performed in 1 case in which renal failure was established, but the patient died.

In none of the published reports of cases is there evidence that operative surgical treatment played any part in saving the life of the patient. The case for amputation remains unproved. Ablation of crushed arms probably is never indicated; but in view of the poor prognosis which accompanies extensive crushing of the leg, the application of a tourniquet to the limb before or at the time of release from the crushing force by a competent physician attached to the rescue squad followed by early amputation as soon as shock has been controlled appears to be rational. Yet Belsey admits that many limbs might be sacrificed unnecessarily by such a course and says that until the crush syndrome can be reproduced experimentally and the fatal renal complications averted by early amputation, such reasoning should be applied to treatment of human beings only with extreme caution.

McMichael [3] discusses the effects on the kidney of trauma to parts other than the urinary tract, and he includes the crush syndrome in his consideration. He states that although final conclusions regarding therapy cannot be arrived at the problem of treatment can now be approached on a rational basis. Instead of the physician's waiting two or three days to find out whether or not renal damage is manifest, he must consider the state of the kidney from the outset. It should be impressed on members of rescue parties that the real danger threatening people who have crushed limbs is that of renal failure. Before the patient is released, therefore, every effort should be made by means of the abundant employment of warm drinks to insure a good flow of urine. The advantage of good diuresis may be: (1) dilution of chemical poisons within the renal tubules and (2) prevention of precipitation of myohemoglobin casts.

Alkalinization of the urine seems to be advantageous, and it is certainly a rational procedure to give alkalis, because the alkaline reserve of these patients often is greatly reduced. Sodium bicarbonate and sodium citrate should be administered orally from an early stage twice to three times an hour, in doses of 2 to 4 Gm. Other diuretic agents can be tried, but there is little evidence as yet to favor any particular one. Administration of a 10 per cent solution of the sodium salt of ortho-hydroxy-mercuric-methyoxy-propylcarbamylphenoxy-acetic acid (mer-

3. McMichael, J., in Discussion on the Effects on the Kidney of Trauma to Parts Other Than the Urinary Tract, Including Crush Syndrome, Proc. Roy. Soc. Med. **35**:333 (March) 1942.

salyl) has been a failure more often than it has succeeded, and since this drug may be a tubular cell poison, it is safer to avoid its use.

Riddell [4] discusses the effects on the kidney of trauma to parts other than the urinary tract, and he mentions the crush syndrome. He says that if a large number of casualties are admitted to the hospital, it is easy for physicians to miss the early crush syndrome unless the casualties are systematically examined. Such a patient often seems to be in good condition and for this reason may temporarily be passed over, so to speak, in favor of examination of some one in a neighboring bed who appears to be more dangerously ill. The only way to avoid this and other mistakes, Riddell says, is to examine each patient in turn, however rapidly, from head to foot, and then if the crush syndrome does not chance to be present, the telltale wheals or simply a localized erythema of the skin will draw attention to the lesion. The nurse in charge can then be warned as to what is likely to happen; the first quantity of urine passed can be saved, and investigation can be begun at the earliest moment.

Robertson and Mathews [5] discuss the crush syndrome and report a case. They say that the duration of the crushing varies greatly and that there does not appear to be any direct relation between the duration and the subsequent seriousness of the condition. The shortest period recorded of crushing which has been followed by the development of the crush syndrome is three hours, and the longest, twenty-six hours. The average period is about ten hours.

In addition to the evidences of shock, physical examination at the outset discloses tenderness and edema and sometimes bruising over the affected parts. There may be whealing of the skin; if this is not present early, it frequently develops later. The involved limbs often are partially or completely paralyzed, and sensation usually is diminished or absent. Arterial pulsation may be reduced, and in several cases in which the edema has progressed, pulsation has disappeared entirely.

Initial shock apparently is controlled by ordinary measures, such as rest in bed, the application of heat and the administration of morphine sulfate. Later, shock reappears and is evidenced by pallor or cyanosis, cold sweating of the extremities, rapid pulse, subnormal temperature, low blood pressure, leukocytosis and, in almost every case, marked hemoconcentration. This episode is controlled by more vigorous measures, such as the administration of oxygen and the intravenous administration of fluids.

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4. Riddell, V. H., in Discussion on the Effects on the Kidney of Trauma to Parts Other Than the Urinary Tract, Including Crush Syndrome, Proc. Roy. Soc. Med. **35**:334 (March) 1942.

5. Robertson, H. R., and Mathews, W. H.: Crush Syndrome, Canad. M. A. J. **46**:116-120 (Feb.) 1942.

During the course of the next few days shock does not recur but the patient remains ill. He is drowsy and apprehensive and vomits frequently. The tongue is dry and coated and the breath foul. The blood pressure tends to increase daily. The urinary output is low, and the values for blood urea and blood potassium are high. Edema increases, and, particularly if the administration of fluid is forced, the blood becomes more and more dilute.

Recovery is heralded by an increase in urinary output with a corresponding decrease in the edema and lowering of the values for urea and potassium in the blood. Blood pressure declines as recovery progresses. As a rule, if the patient survives the affected limb returns to normal.

Death, when it occurs, comes rather suddenly—somewhere between the seventh and the tenth day. The mortality rate associated with the condition is difficult to assess at present. Undoubtedly many patients whose condition may be mild or severe escape notice. Study of the reported cases reveals that few patients in whom the syndrome was fully developed survived.

The observations made at postmortem examination in cases of crush syndrome are distinctive and center in two sites: the kidneys and the skeletal musculature. Macroscopically the kidneys reveal only congestion and edema, but they exhibit well marked microscopic changes which center chiefly in the renal tubules. The glomeruli show no histologic alteration but do reveal the presence of an albuminous material in Bowman's capsule. The epithelium of the convoluted tubules and the loops of Henle contains some degenerative changes and may be shed and mingle within the tubules with eosinophilic coagulum. The striking observation is that of pigment casts, which may be present in the loops of Henle but more abundantly in the collecting tubules.

Observations concerning the urine are as follows: The volume is low. The specific gravity is fixed at about 1.015. The urine is acid. Albumin invariably is present. Leukocytes are commonly found. Erythrocytes have been found in several cases but are not always present. Granular pigmented casts are found in every case in which the condition is typical. In association with these facts, the reaction to the benzidine test for blood is almost always positive.

The shock exhibited in these cases is treated by the usual methods. The real problem concerns the treatment of the later-developing oliguria. Diuretic agents (such as hypertonic solution of dextrose, caffeine, mercury and others) have been used without effect. Large amounts of fluid have been administered in every case, and usually the only observed result has been an increase in the edema. Hot packs applied over the renal regions are of no apparent benefit.

Various surgical procedures have been suggested. These include amputation (performed in 1 case without success), incision through

the deep fascia in an attempt to reestablish circulation cut off by edema and decapsulation of the kidneys. The use of elastoplast on the edematous limb has been suggested.

Recently, several cases of recovery have been reported, and in these the success has been attributed to the administration of alkalis. The rationale of alkaline therapy is based on two facts: (1) that the patients all have marked acidosis and (2) that it is probable that, like hemoglobin, the pigment found in these cases is precipitated in the tubules if the urine is acid, whereas if the urine is alkaline the pigment will pass through without the infliction of renal injury.

Longland and Murray administered 360 grains (about 23 Gm.) of potassium citrate by mouth daily for four days and 480 cc. of a 3.3 per cent solution of sodium sulfate intravenously on the third of these days before the urine became alkaline. Henderson administered 540 cc. of a 3.3 per cent solution of sodium sulfate intravenously daily for four days. Blackburn and Kay administered 1,000 cc. of a 2 per cent solution of sodium bicarbonate rectally on the fifth day after injury and later (on the eighth day) started to administer sodium bicarbonate orally, giving a total of 96 Gm. in seven days.

At present it appears that the administration of alkali in doses sufficient to alkalinize the urine is of prime importance in the treatment of these patients. Presumably, the earlier the administration of alkali is started, the more likely is it to be of benefit.

Anomaly.—Anson, Pick and Cauldwell[6] discuss the anatomic aspects of renal anomalies. In serial dissection of 2 specimens of anomalous kidneys, they discovered anatomic features which are of surgical importance. These features are concerned chiefly with portions of the renal regions which could not or would not be studied in the course of the usual urologic operation or routine postmortem examination; these areas are the sites of complex arterial and venous anastomoses between renal vessels and almost all vascular channels of the abdominal wall.

The ectopic (pelvic) kidney lies in front of the sacral promontory, they state, just to the right side of the midline. Its renal artery and two renal veins follow an almost vertical rather than a transverse course. In passing along the kidney the vessels groove the renal parenchyma, and the sulci thus formed are more striking than the renal hilus.

Of almost equal importance is the set of vessels with which the ectopic kidney is brought into relation posteriorly and laterally. The

6. Anson, B. J.; Pick, J. W., and Cauldwell, E. W.: The Anatomy of Commoner Renal Anomalies: Ectopic and Horseshoe Kidneys, J. Urol. **47**:112-132 (Feb.) 1942.

kidney rests on the common iliac artery and the corresponding veins; these in turn overlie the sacral plexus and the sympathetic trunk. The bed of the kidney is therefore composed almost totally of the large pelvic arteries and veins, an anatomic arrangement of grave importance in urologic surgery.

In the specimen of horseshoe kidney which they studied, the renal arteries and veins with the aorta and the inferior vena cava and the related adrenal and testicular blood supply formed a quadrilateral maze of vessels the boundaries of which were the mesenteric arteries above and below and the outer margins of the psoas major muscles on each side. Both sets of adrenal arteries were closely associated with superiorly placed renal arteries; as usual, they were numerous and complex, whereas the adrenal veins were solitary in arrangement. Sympathetic nerve plexuses crossed the isthmus of the fused kidneys to become the presacral nerve below the aortic bifurcation.

Hydronephrosis.—Hagenbach [7] reports 7 instances of hydronephrosis among children. In 6 cases the kidney was removed, and in the seventh case a large aberrant vessel was resected. In this case an examination of the patient nine years later showed hydronephrosis still present.

Sargent [8] discusses the basic principles governing conservative surgical operation in hydronephrosis. He states that hydronephrosis is not the unilateral disease that it has been so commonly thought to be. Nephrectomy for hydronephrosis in one kidney can and sometimes does initiate the rapid development of hydronephrosis on the opposite side.

Plastic reconstruction of the ureteropelvic juncture is a perfectly safe and practicable surgical procedure.

Once ureteropelvic obstruction has been successfully overcome (unless the kidney is hopelessly dead to begin with), there follows a succession of events—anatomic involution, decrease of infection and recovery of function that is always impressive and sometimes even unbelievable.

It is impossible by the use of any one particular method to correct the wide variety of pelvic deformities that are encountered, and Sargent believes that good results are most likely to be gained by fitting the proper procedure to the particular type of deformity at hand. Performance of protective nephrostomy is absolutely indispensable when the pelvis has been opened for a plastic surgical operation. A splinting

7. Hagenbach, E.: 7 Fälle von kindlichen Hydronephrosen, Schweiz. med. Wchnschr. **70**:226-229 (March) 1940.

8. Sargent, J. C.: Basic Principles Governing Conservative Surgery in Hydronephrosis, J. Urol. **47**:323-343 (March) 1942.

catheter is of considerable help, provided it is sufficiently small to fit loosely within the ureter. Wounds caused by plastic surgical operations on the ureter and the pelvis heal readily. Nephrectomy should be reserved for those cases of hydronephrosis in which the kidney is known to be utterly worthless and for those occasional cases in which plastic surgical procedures have been undertaken and have failed.

Stone.—Creevy [9] discusses nephrolithiasis caused by infection with members of the genus Proteus.

Organisms of this genus probably reach the urinary tract only through instrumentation, although Chute had 2 patients who had had no such history. The organisms are common residents of the human bowel, having been found on a single culture of the stools of 22 of 53 patients taken consecutively at random. The organisms may be present about the external urinary meatus and may be introduced by a urethral instrument, or may grow along the outer surface of an inlying catheter. Such a catheter, whether it is situated in the urethra, in a suprapubic fistula or in the kidney, may be contaminated either directly or from linen not grossly soiled. The route by which the organisms, once they have been introduced into the bladder, invade the kidneys is not definitely known. They may, however, arrive by way of the blood stream. Theoretically, of course, they may ascend the periureteral lymphatic vessels or the lumen of the previously diseased ureter or follow the lymphatic vessels from the ascending portion of the colon to the right kidney. The latter route may account for those infections which arise in the absence of instrumentation. According to the literature members of the genus Proteus are not common invaders of the urinary tract; they occurred in only 135 (5.4 per cent) of 2,502 cases of urinary infection in five reported series.

The relative infrequency of infection caused by these organisms is in striking contrast to the potential seriousness of the infection to the afflicted person. The peculiar menace of the organisms is their ability to break down the urea of the urine into carbon dioxide and ammonia, the latter of which makes the urine strongly alkaline.

The organisms are found in but a small proportion of instances of renal and ureteral lithiasis. Of 2,537 cases of stone collected from ten reports in the literature, data as to infection were complete in 2,191. In 65 per cent of these cases infection was associated with bacteria in the urine. In 6.2 per cent of the whole group and in 11 per cent of the cases of infection, members of the genus Proteus were found.

The organisms occur relatively more often in the presence of recurrent stones than in the presence of primary stones. Swift-Joly

9. Creevy, C. D.: Nephrolithiasis Due to Infection with the Bacillus Proteus, Surgery **10**:971-984 (Dec.) 1941.

and many others have found that nearly all recurrent stones are associated with infection and that if postoperative infection caused by urea-splitting organisms occurs recurrence is almost certain to take place. Chute reports that in 13 of 26 cases of recurrent stones the calculi were due to infection with organisms of the Proteus group, and Twinem found the organisms in 7 of 10 patients who had repeated recurrences after operation.

Once stones begin to form in the kidneys as a consequence of infection with these organisms, the outlook is black indeed unless stones, predisposing causes (particularly stasis and immobilization in recumbence) and the exciting organism all can be removed. If the urinary tract is normal except for the infection, the organisms can be easily killed by acidification of the urine and the administration of mandelic acid.

In summary, Creevy reports 13 cases in which nephrolithiasis secondary to infection by members of the genus Proteus occurred. In 11 of the 13 patients (84 per cent), the infection was known to have been introduced by catheters, such as are usually employed in nephrostomy or cystostomy. In 2, congenital anomalies of the urinary tract were present. In 9 (70 per cent), the calculi were bilateral; in 2, the calculi grew rapidly under observation. Five (38 per cent) of the patients died, 4 as a direct result of the infection and lithiasis and 1 from a surgical accident.

Treatment of the patients seen earlier in the series was entirely futile, but Creevy says that treatment is gradually improving for four reasons: (1) development of effective urinary antiseptic agents (sulfanilamide and especially sulfathiazole [2-(paraaminobenzenesulfonamido)-thiazole]) and of the citrate–citric acid irrigants; (2) clear understanding of the mode of entrance of the organisms into the urinary tract; (3) appreciation of the extraordinary serious potentialities of these organisms, and (4) comprehension of the roles of predisposing factors, such as stasis and recumbency.

He concludes that the real solution of the problem lies, however, not in the removal of stones, relief of stasis and cure of infection but in the prevention of the entrance of the organisms into the urinary tract by adequate, painstaking and persistent attention to proper sterilization of catheters and their adjuncts, to their aseptic introduction and fixation and above all to the proper care of the systems draining urine from the body. To this end, he says, educational activities by informed urologists are imperative.

Priestley and Schulte [10] state that approximately 85 per cent of patients who have renal or ureteral calculi which require surgical

10. Priestley, J. T., and Schulte, T. L.: Simultaneous Bilateral Operation for Renal and Ureteral Calculi, J. Urol. **47**:255-257 (March) 1942.

treatment have stones in one side of the urinary tract only. In the remaining 15 per cent of cases bilateral calculi are present.

There are several types of cases in which the simultaneous bilateral operation might be of value. In the event of bilateral ureteral obstruction by stone it is of advantage to relieve the obstruction on each side at the earliest possible time. Especially is this important if a serious degree of infection is present. Should this condition exist on both sides at the same time, it seems worth while to relieve the obstruction to both ureters at the same operation, provided the patient presents himself as a fair operative risk. Likewise, if pyonephrosis with stone exists on one side and a simple stone readily removable by operation is present on the other side (particularly if it has caused or is causing obstruction), the bilateral simultaneous operation may be advisable. By this procedure renal function is maintained by removal of the stone on the side of the functioning kidney and the source of infection and possible postoperative complication presented by the pyonephrosis are removed at the same time.

There are other combinations of bilateral calculous disease in which use of the bilateral simultaneous operation may be optional. Such might be a virtually functionless kidney on one side associated with calculous disease and a single calculus in the opposite kidney. Likewise, bilateral single renal calculi, neither of which is causing urgent symptoms, with adequate renal function and little infection may or may not be removed at one operation; this depends on the discretion of the surgeon. In general there are two main types of cases in which the bilateral simultaneous operation may be considered, namely, the case in which the patient is in good condition with normal renal function and a readily removable calculus on each side and, in contrast, the case in which the patient is critically ill with serious calculous disease which is jeopardizing his well-being in each kidney or ureter, either of which by itself demands immediate surgical attention.

The obvious advantages of the simultaneous bilateral operation in addition to relief of an acute condition on both sides are largely economic. The period of hospitalization and disability is definitely reduced. Probably it is unwise to plan operation on both sides of the urinary tract for stone at one time if operation on either side is unusually difficult. Thus in the presence of large recurrent renal calculi the unilateral operation generally is enough for the patient at one time.

Cyst.—Lüdin and Howald [11] report a case of intrarenal cyst. The walls of the cyst were covered with calcium carbonate and phosphate crystals. The cyst was removed surgically, and healing took place

11. Lüdin, M., and Howald, R.: Eine eigenartige, intrarenale Zyste, Schweiz. med. Wchnschr. **70**:230-232 (March) 1940.

without incident. Lüdin and Howald discuss the possibility of the cyst's arising from an aberrant calix.

Rudström [12] reports a case in which a renal cyst containing about 2,000 small rounded concretions of approximately equal size passed spontaneously. There was no evidence of urinary infection. Analysis of the concretions showed them to be composed of an albumin stroma incrusted with calcium phosphates and carbonates. The cystic cavitation which filled with contrast medium from the renal pelvis on intravenous and retrograde pyelography was regarded as being an intrarenal solitary cyst that had invaded the renal pelvis. The renal cyst was thought to be the center of formation of the concretions. Rudström records another case of similar formation of a cyst (without concretions) and refers to 2 cases in the literature in which similar concretions in kidneys with cystic changes were reported.

Tuberculosis.—Braasch and Sutton [13] state that a difference of opinion exists as to the clinical data necessary to establishment of the diagnosis of renal tuberculosis in cases in which the diagnosis is doubtful. They believe that the presence of Mycobacterium tuberculosis in the renal urine obtained by catheterization as determined by positive results of inoculation of guinea pigs is not sufficient. They say that in addition there should be at least 3 to 10 pus cells per field under the high power objective and that in some cases positive urographic deformity will have to be noted to make the diagnosis certain. Among the 2,200 patients having renal tuberculosis observed at the Mayo Clinic, Rochester, Minn., during the years 1910 to 1934 inclusive, the condition of 291 (13 per cent) was diagnosed as bilateral renal tuberculosis. Eighty-seven of these 291 patients underwent nephrectomy, and 204 were not operated on. Braasch and Sutton say that nephrectomy in the treatment of bilateral renal tuberculosis is indicated only when there is a decided difference in the extent of the lesion in the two kidneys and only when the diseased kidney is the cause of the symptoms which require relief. They believe that a clearcut history of a period of dysuria and frequent micturition many years prior to examination with a history of recent recurrence is typical of bilateral involvement. Furthermore, it has been their impression that the previous occurrence of tuberculosis in other tissues often seems to increase the patient's resistance and may be conducive to a relatively good prognosis. They have noted also that in spite of advanced bilateral involvement of both kidneys the combined renal function is often normal or reduced only slightly. The incidence of hypertension among their patients was only a little higher than the average incidence of hypertension observed

12. Rudström, P.: Ein Fall von Nierenzyste mit eigenartiger Konkrementbildung, Acta chir. Scandinav. **85**:501-510, 1941.

13. Braasch, W. F., and Sutton, E. B.: Prognosis in Bilateral Renal Tuberculosis, J. Urol. **46**:567-578 (Oct.) 1941.

among adult persons traced. The clinical course of 167 patients revealed that the survival rate for patients traced for three years or more was about 72 per cent; for five years or more, 58 per cent; for ten years or more, 28 per cent, and for fifteen years, 16 per cent. Most of the patients who were living ten or fifteen years after examination were in a fairly normal condition except for a variable degree of frequency of micturition. It is the impression of the authors that previous concepts concerning expectancy of life in case of nonsurgical renal tuberculosis demand radical revision and that unless the indications for nephrectomy are definite in a case of bilateral disease it is well to give nature a chance rather than to intervene.

Wasserfallen,[14] in a review of the records of patients with tuberculosis in a sanatorium in Leysin, Switzerland, found that in 5.5 per cent of the patients with pulmonary tuberculosis and in 14.4 per cent of the patients with surgical tuberculosis renal tuberculosis was also present. Among none of the patients for whom the results of inoculation of guinea pigs had been positive was there found genuine tuberculous bacilluria. Wasserfallen does not think that nephrectomy is always immediately necessary, even when a positive diagnosis is reached.

Tuberculoma.—Bugbee[15] reports a case of tuberculoma of the kidney. The patient, a woman 30 years old, had pus and acid-fast bacteria in her urine. Excretory urograms disclosed normal filling of the right kidney and a filling defect suggestive of a tumor on the left. Nephrectomy was done on the left side, and the pelvis of the kidney was found to be filled with a smooth pink firm mass which had the appearance of a renal tumor. Zones of necrosis were not observed, nor were any tubercles seen. Sections made throughout the kidney, including the large nodule in the center, were involved by active tuberculosis and by the rapid formation of tubercles, with many endothelial cells and diffuse lymphoid infiltration. These tubercles were confluent and discrete and were found throughout the kidney from the pelvis to the cortex. The nodules on the surface also were seen to be tubercles.

Bugbee states that in this case an early stage of the disease was represented, in which the tuberculous process presented definite formation of tumor. Necrosis and cavity formation had not taken place, and although there were definite hemorrhagic portions in the bladder, the ureter apparently was not involved.

Wilms's Tumor.—Priestley and Schulte[16] review a series of 39 cases of Wilms's tumor in which nephrectomy had been performed five

14. Wasserfallen, M.: Remarques sur la tuberculose rénale, Schweiz. med. Wchnschr. **70**:184-185 (March) 1940.

15. Bugbee, H. G.: Tuberculoma of the Kidney: Report of a Case, Tr. Am. A. Genito-Urin. Surgeons **34**:15-18, 1941.

16. Priestley, J. T., and Schulte, T. L.: The Treatment of Wilms' Tumor, J. Urol. **47**:7-10 (Jan.) 1942.

years or more prior to the follow-up study which they present. Six of the 39 patients, or 15 per cent, were living five years or more after nephrectomy. Various forms of treatment of Wilms's tumor, namely, irradiation alone, operation alone, irradiation followed by operation, operation followed by irradiation, and irradiation followed by operation and subsequently further irradiation, were considered. The authors favor the last form of treatment with a relatively short period of preoperative irradiation, usually accomplished within ten days to two weeks. In the exceptional case in which the tumor is small when it is first seen, immediate nephrectomy followed by postoperative irradiation can be employed. Twelve patients were treated by preoperative irradiation, nephrectomy and postoperative irradiation, and the results obtained in this group were the best of any. Three of these 12 patients (25 per cent) were living five or more years after operation at the time of the authors' report.

Pyelonephritis.—Gloor [17] reports 7 cases of shrunken or atrophic kidneys. In 5 of these the patients came to necropsy, and the pathologicoanatomic examination in all 5 cases confirmed the clinical diagnosis of renal hypoplasia.

Most of the patients were young; 6 of them were between 20 and 45 years of age. The blood pressure of these patients varied between 100 and 130 systolic and 80 and 100 diastolic; in 1 case in which glomerulonephritis complicated the situation there was terminal hypertension of 175 systolic and 120 diastolic. The value for urea varied from 51 to 339 mg. per hundred cubic centimeters of blood. Most patients have a fairly high degree of albuminuria. Results of microscopic examination were not typical; usually, a few pus cells and only rare casts appeared. A large number of leukocytes was found only in those cases in which secondary infection had occurred. The urine was sterile in 4 cases; in 3, numbers of Escherichia coli were observed.

The pyelograms all disclosed small, triangular renal pelves, the calices being close together (typical) and pyelograms depicting atrophic pyelonephritis.

Numerous associated anomalies, such as hypospadias, spina bifida and changes of the location of the ureteral orifices, suggested an anomalous origin of the renal condition. The smallest kidney weighed 15 Gm., and the largest, 90 Gm.

Histologic examination showed two different structures of tissue: (1) normally constructed renal parenchyma with well developed glomeruli and tubuli and (2) portions of stroma-like transformation of the entire parenchyma. Cysts of different sizes pressed closely together

17. Gloor, H. U.: Die hypogenetische Niere und ihre Bedeutung im Problem der renalen Blutdrucksteigerung, Ztschr. f. urol. Chir. u. Gynäk. **46**:7-56, 1941.

and filled with a colloidal substance frequently were seen. Partial hyalinization of the glomeruli was pronounced.

Gloor notes that in all these cases hypertension was not found and states that hypertension as a rule results only when a large number of glomeruli are affected.

Likely, Lisa and Solomon [18] review 93 cases in which patients who had uremia came to necropsy. In this group were 32 patients with pyelonephritis. Twenty-two of these died of uremia. Most of the patients had degenerative cardiovascular renal disease. The series illustrates the importance of long-standing pyelonephritis as the basic pathologic condition in a large proportion of the mass of those patients seen in hospital practice who usually are grouped as having degenerative diseases.

Hypertension and Renal Disease.—Abeshouse [19] states that the diagnosis of essential hypertension should be made with great reservation. Every patient who has hypertension of unknown causation should be given the benefit of comprehensive study of the entire body, including complete urologic study. The value of this type of investigation is emphasized by the frequent occurrence of urologic lesions among hypertensive patients, as indicated in recent clinical and statistical reports.

Abeshouse says that the presence of a urologic lesion in a hypertensive patient must be carefully evaluated from the standpoint of causation, for not infrequently such a lesion is coincidental and bears little causal relation but may influence considerably the clinical course of the hypertension.

In some cases the blood pressure returns to and remains at a normal value after the performance of nephrectomy, an occurrence which can be attributed to the fact that unilateral renal disease was the primary factor responsible for the hypertension and that secondary arteriolar changes in the opposite kidney or in other parts of the body either were absent or had not progressed to an irreversible degree.

In other cases the end results from the standpoint of reduction in arterial blood pressure were not so striking after nephrectomy, i. e. the immediate effect was a transitory lowering of the blood pressure for a few weeks or months followed by a gradual return to preoperative values.

Abeshouse says it is important that an adequate period of time (at least a year) elapse after operation before the urologist attempts to evaluate the permanency and the extent of the reduction in arterial

18. Likely, D. S.; Lisa, J. R., and Solomon, C.: Pyelonephritis, with Death in Uremia, J. A. M. A. **119**:397-400 (May 30) 1942.

19. Abeshouse, B. S.: Hypertension and Unilateral Renal Disease: Review of the Literature and Report of Sixteen Cases, Surgery **10**:147-200 (July) 1941.

blood pressure. In view of the uncertain end results that have been obtained and the insufficient period of observation mentioned in the reported cases, he thinks there is no justification for the consideration of nephrectomy as a panacea for the cure of hypertension in every case of chronic unilateral disease of the kidney.

Abeshouse concludes that every clinician and urologist should recognize the limitations of and contraindications to nephrectomy in the treatment of hypertension associated with unilateral renal disease. It must be remembered, he says, that nephrectomy may be fatal in instances of hypertension of long duration or in cases in which the clinical course is suggestive of so-called malignant hypertension.

Gibson [20] states that experimental evidence has shown that ischemia is the essential factor which causes hypertension in renal disease. Renal ischemia results in the liberation from the kidney of a vasoconstrictor or pressor substance called renin. Analysis of clinical reports indicates that many types of lesions of the kidney may cause hypertension. These lesions can be classed into three general groups: (1) gross vascular lesions of the renal artery or its branches; (2) the obstructive so-called uropathies, and (3) chronic inflammatory lesions. In all three groups, Gibson says, clinical evidence supports the experimental evidence which indicates that ischemia is the important factor in initiating hypertension.

Chronic infection appears to be the most important single causative factor in the production of renal ischemia. It is estimated that from 15 to 20 per cent of instances of malignant hypertension are caused by chronic pyelonephritis, even though in some cases the infection has run its course and has healed. Gibson thinks all patients who have hypertension should be given the benefit of complete urologic investigation as a part of their routine examination, even in the absence of signs or symptoms of disease of the urinary tract. Reasonable expectancy of improvement or cure of hypertension of renal origin can be hoped for by appropriate treatment of the pathologic process or processes thus revealed in the opinion of Gibson.

Powers and Murray [21] report a case of what is called juvenile hypertension, secondary to unilateral disease of the kidney. They classify the renal lesions as primarily neoplastic, obstructive, congenital or inflammatory. They state that thorough investigation of the urinary tract should be carried out for every child who has a previous history of pyelitis or pyelonephritis and who has symptoms referable to the

20. Gibson, T. E.: Hypertension and the Surgical Kidney, California & West. Med. **56**:66-70 (Feb.) 1942.

21. Powers, J. H., and Murray, M. F.: Juvenile Hypertension Associated with Unilateral Lesions of the Upper Urinary Tract, J. A. M. A. **118**:600-604 (Feb. 21) 1942.

central nervous system, the cardiovascular system, the gastrointestinal tract or the genitourinary tract. The same investigation should be pursued in every case of unexplained juvenile hypertension. If disease of one kidney is discovered, the patient should be treated by operation, provided the function of the opposite kidney is essentially normal and the general condition of the child is adequate for him or her to withstand surgical intervention.

The authors say that with the exception of cases in which hypertension was secondary to renal neoplasm the immediate results of operative treatment in all reported cases, including the one they contribute, have been excellent. Too little time has yet elapsed for it to be possible to state with certainty that the hypertension in any case has been permanently relieved, they say.

Allen [22] discusses peripheral ligation in relation to blood pressure and states that the dog is highly subject to psychic or nervous hypertension, apparently to a greater degree than is man. The results of ligation of various parts of the body, duplicating those previously obtained concerning the kidneys, confirm the interpretation that the phenomenon is not humoral or specific to the kidneys but is purely nervous.

A strong psychic factor is obvious in all the experiments in which ligation or clamping of the kidneys, the testes, the legs, the tail and the ears was done, but the occurrence or persistence of some elevation of pressure under conditions of mild anesthesia or psychic quietness, so to speak, indicates that an additional nervous mechanism, apparently reflex, operates.

Without prejudice to the results of other writers who have demonstrated the production of a hypertensive substance in the asphyxiated kidney under special conditions, results of the present experiments, Allen says, show that the secondary increase in pressure which follows prolonged ligation of explanted kidneys sometimes may be matched by similar occurrences with the testes and tail, in which case it is evidently a nervous response to the painful local inflammation. Since acute hypertension arising from ligation of organs or from simple excitement occurs in epinephrectomized animals, Allen suggests that the adrenal bodies apparently are not concerned in the process.

Braasch, Walters and Hammer [23] report that hypertension frequently was found in association with a unilateral lesion of the kidney and that rather often it could be relieved by surgical operation. They have analyzed records of a group of 1,184 patients who underwent renal

22. Allen, F. M.: Peripheral Ligations in Relation to Blood Pressure, J. Urol. **47**:431-439 (April) 1942.

23. Braasch, W. F.; Walters, W., and Hammer, H. J.: Hypertension and the Surgical Kidney, J. A. M. A. **115**:1837-1841 (Nov. 30) 1940.

surgical exploration and found that the incidence of hypertension in this group was no higher than that found in a group of patients whose records were taken at random. They found also that the renal disease amenable to surgical treatment which occurs most often in association with hypertension is atrophic pyelonephritis. Seven of 10 patients (70 per cent) who had this condition were relieved of their hypertension. Hypertension was observed in 161 patients, or 20.3 per cent, of 793 for whom operation was performed for renal stone. The authors say that the role of secondary infection is important, since hypertension occurred in 22.5 per cent of cases in which infection was manifest and in only 5.7 per cent of cases in which there was no infection. The blood pressure returned to normal and remained normal after surgical intervention in approximately 23 per cent of the cases in which hypertension had been present preoperatively. Braasch, Walters and Hammer note that hypertension was present in approximately 14 per cent of patients with hydronephrosis without stone on whom operation was performed. Among the 29 patients who had had hypertension preoperatively there were 10, or 34.4 per cent, whose blood pressure returned to normal and remained so for one year to five years. Hypertension was observed in only 12, or 7.6 per cent, of the 158 patients with renal tuberculosis whose records were studied. Eleven of these patients were traced, and among these the blood pressure of 7 returned to normal. Hypertension was found in 38 cases, or 29.7 per cent, of 137 cases in which operation had been performed for renal adenocarcinoma. According to the authors there are not enough cases of renal neoplasm other than hypernephroma to allow an accurate survey of each type to be made. Hypertension was noted in 6 cases of epithelioma of the renal pelvis, and the blood pressure returned to normal in only 1 case. The blood pressure was recorded in 18 cases of Wilms's tumor and definite hypertension was noted in only 5. Among the 21 patients with hypernephroma complicated by hypertension, the blood pressure of 9 returned to normal; 3 of the patients experienced a temporary decrease in blood pressure and subsequently a return of hypertension. Of particular interest was a case of polycystic disease with hypertension in which one kidney had become functionless as a result of diffuse infection. The blood pressure of the patient decreased to normal after nephrectomy and remained normal for the year that the patient was followed.

Of further interest to the authors was a series of 14 patients whose blood pressure had been normal prior to conservative renal operation and in whom hypertension developed after operation. Urologic examination of these patients revealed evidence of reduced function and persistent infection in the kidney which previously had been subjected to operation. After removal of the kidney, the blood pressure of the

patients returned to normal. The authors conclude that a postoperative increase in blood pressure apparently occurs more frequently after a conservative operation for renal and ureteral lithiasis than it does after operations for other lesions. Renal insufficiency was not found to be causative of hypertension in the cases in which renal surgical operation had been performed. Since hypertension is caused by factors other than those relative to the kidney in most cases, the authors conclude that nephrectomy may be contraindicated in cases in which hypertension accompanies a surgical renal lesion, if any of the following factors are present: (1) bilateral renal disease so extensive that removal of one kidney would be of no benefit; (2) existence of hypertension of long standing with such extensive secondary degenerative lesions in other organs that removal of a diseased kidney would no longer influence the subsequent clinical course; (3) evidence of advanced renal insufficiency, and (4) existence in another organ of an unrelated serious lesion which in itself might be regarded as inoperable.

Wilson and Chamberlain [24] discuss unilateral renal ischemia associated with hypertension and report a case in which a 12 year old girl had severe headache, partial blindness and blood pressure of 230 systolic and 170 diastolic. Cystoscopy indicated that she had a small, functionless right kidney. This kidney was removed through a surgical incision and was found to weigh only 11.5 Gm. It was scarred, atrophic and fibrotic. After removal of this kidney the blood pressure decreased, and during the next year it remained at 120.

To ascertain whether there was any association between perinephritis and hypertension, Braasch and Wood [25] reviewed a series comprised of 70 patients encountered consecutively during a ten year period in whom the primary disease process was perinephritis. This study was instigated by the work of Page in 1939, who reported the development of hypertension in dogs after the application of a loose jacket of cellophane to either one kidney or both kidneys. In the entire series of 70 cases there were only 3 in which some correlation of hypertension with perinephritis might be established, and the authors conclude that the clinical association between perinephritis and hypertension is so slight as to be of little or no significance.

URETER

Obstruction.—Hoffman [26] has studied a series of 97 patients in whom ureteral obstruction followed radiation treatment of cancer of the cervix,

24. Wilson, C. L., and Chamberlain, C. T.: Unilateral Renal Ischemia Associated with Hypertension; Case Report, J. Urol. **47**:421-430 (April) 1942.

25. Braasch, W. F., and Wood, W. W., Jr.: Clinical Perinephritis and Blood Pressure, Proc. Staff Meet., Mayo Clin. **17**:52-54 (Jan. 28) 1942.

26. Hoffman, P. E.: Ureteral Obstruction Following Irradiation Treatment of Cancer of the Cervix, West. J. Surg. **50**:69-72 (Feb.) 1942.

dividing them into different groups depending on the severity of the disease.

In group 1, all members of which were treated with radium only, there was only 1 instance of ureteral involvement during the three year period in which these patients were studied. Renal pain developed in the patient after two years, and she was found to have stricture. She rapidly improved and became symptom free after a series of ureteral dilations.

In group 2, comprised of 23 patients, 18 received radium and 5 received radium plus high voltage roentgen therapy. Only 1 patient in this group was found to have any initial renal pathologic process. She had slight hydronephrosis on the right, which after a series of ureteral dilations did not progress. Three of these patients had died at the time of Hoffman's report, but they had no involvement of the urinary tract. In 1 patient after a year there developed an obstruction of the right ureter 3 cm. from the ureteral orifice, with complete loss of function of the kidney, in spite of repeated dilations.

In group 3, composed of 40 patients, the treatment of 37 was high voltage roentgen therapy plus radium, and of 3, radium alone. The initial urograms disclosed that 16 had some type of renal pathologic process. Among 4 of the 24 patients who did not have any renal pathologic process on admission, unilateral obstructive ureteral lesions developed within six months, and 2 others had died at the time of Hoffman's report—one of metastasis to the lungs and the other of metastasis to bone. The other 18 had remained free of ureteral obstruction to the time of Hoffman's report.

Of the 20 patients with renal involvement, 6 died within three years. Of the 21 patients in group 4, 9 received high voltage roentgen therapy only; 2, radium therapy, and 10, high voltage roentgen therapy plus treatment with radium. The initial urograms disclosed that 13 had a ureterorenal pathologic process of some type. All the 8 patients who had no urologic involvement were living after three years (at the time of the Hoffman report). Three patients who had urinary involvement when first seen experienced progressive total loss of function in the affected kidney with compensatory hypertrophy taking place in the other kidney. Ten patients died within or shortly after three years. In every instance necropsy revealed marked involvement of the ureters with the inevitable effect on the kidneys.

Hoffman's procedure has been, he says, to dilate the ureters, and generally he has used the direct vision air cystoscope and Kelly catheters of sizes up to F 15 at intervals of ten to fourteen days. Twenty-four patients have been treated in this manner, but in most instances there has been a gradual diminution in the ureteral lumen until it became impossible to pass a dilator past the site of obstruction. Eleven patients

were more intensively treated in the hospital for periods of two to three months. Catheters were passed to the renal pelvis and left in place for periods of twenty-four hours. This procedure generally was repeated within two to four days. There was gradual shrinking of the ureter in spite of this treatment, and finally even small catheters could not be passed, and inevitable loss of the kidney resulted. In only 1 case was a permanent good result produced by ureteral dilation. Hoffman concludes that intensive ureteral dilation of the affected ureter as a means of alleviation of this condition has proved disappointing and says that other methods must be considered.

Wharton [27] presents reports of 7 cases of bilateral simultaneous ureteral obstruction. All the patients had uremia to a greater or a less degree. All would have died if the urinary obstruction had not been relieved. Necropsy of 1 patient who did die disclosed carcinoma of the bladder which surrounded and constricted both ureters. Consideration of these cases makes certain facts clear, Wharton says. Although these facts are undoubtedly well known, these cases show that the layman does not appreciate their significance and that many physicians fail to realize the potential danger of urinary stasis and infection. Among these basic facts are the following:

Chronic pyelonephritis may eventually destroy the kidneys. If it is accompanied by stasis, the damage is increased. The terminal pathologic lesion may be hydronephrotic or pyonephrotic atrophy of a contracted kidney. Hydronephrosis and hydroureter are the usual results of urinary obstruction and infection. But this is not always the case. The pelvis of the kidney may be contracted and smaller than normal, even in the presence of a dense and almost impassible ureteral stricture. Stricture may be complete or incomplete. Both types are of equal potential damage to the kidney. They differ chiefly in the rate at which the damage is inflicted.

An impassable or complete ureteral stricture is easily recognized according to Wharton. The difficulty arises in detection of the incomplete type, especially if the urologist uses a fine catheter. In the interpretation of findings a history of urinary infection and the general clinical picture are just as important as and maybe more enlightening than the urologic observations made at the moment. Correct management of the patients is a matter that requires sound judgment.

Urinary infection and obstruction frequently are insidious. Wharton says that they may be completely asymptomatic, progressing silently until irreparable damage has been inflicted. Elimination of these conditions, even if they are apparently asymptomatic, is essential if renal health is to be conserved.

27. Wharton, L. R.: Simultaneous Obstruction of Both Ureters, with Uremia: Report of Seven Cases, J. Urol. **47**:133-140 (Feb.) 1942.

Tumor.—Cook and Counseller [28] report 18 cases of primary epithelioma of the ureter, the diagnosis being proved in each case by operation. The tumors were graded as follows: 1 was of grade 1; 9 were of grade 2; 7 were of grade 3, and 1 was of grade 4. Of the 10 patients who had grade 1 or grade 2 tumors, 7 were living (1 nine years; 2, three years; 1 two years, and 3, less than one year) at the time of the report. Of the 8 patients who had tumors of grade 3 or 4, only 1 was living; he had been alive for eight years after operation at the time of the report. Hematuria and pain are the two important symptoms. Although excretory urograms frequently may suggest the diagnosis, retrograde pyeloureterography is necessary in most instances to reveal the actual deformity and to establish the diagnosis. Cook and Counsellor believe that the treatment is surgical and that complete extirpation of the kidney, the ureter and the ureterovesical segment of the bladder should be done. All periureteral adipose tissue should be removed with the ureter because of the tendency of this particular type of neoplasm to extend through the wall of the ureter.

Ureterocele.—Thompson and Greene [29] report results of clinical study of 37 cases of ureterocele and emphasize the cause, the diagnosis and the treatment of this condition. The causation of ureterocele is a somewhat controversial question, for the condition is considered by some to be congenital in origin and by others to be of an acquired nature. The consensus favors a congenital origin; however, in certain cases ureterocele has been observed to have been acquired. Twenty-five of the 37 patients were female, and 12 were male. The youngest patient was 9 years of age; the oldest, 64 years. Approximately two thirds of the 37 patients were between 30 and 50 years of age when the ureterocele was first detected. There is nothing characteristic about the symptoms of ureterocele. Pain was the most frequent symptom noted, but vesical symptoms, such as urinary frequency, dysuria and nocturia, often occur. Less frequently, hematuria (gross blood) and the passage of urinary calculi may occur. Five patients without symptoms referable to the urinary tract were studied urologically in an attempt to find the cause of obscure abdominal symptoms; in each case ureterocele was discovered.

Thompson and Greene describe the cystoscopic appearance of ureterocele and emphasize the variations in appearance which depend on the size of the lesion. As observed in an excretory cystogram, a ureterocele appears as a spherical or sausage-shaped filling defect or as an accentuation of the medium situated near the trigonal region and in line with the

28. Cook, E. N., and Counseller, V. S.: Primary Epithelioma of the Ureter, J. A. M. A. **116**:122-126 (Jan. 11) 1941.

29. Thompson, G. J., and Greene, L. F.: Ureterocele: A Clinical Study and a Report of Thirty-Seven Cases, Proc. Staff Meet., Mayo Clin. **17**:133-136 (March 4) 1942.

terminal portion of the ureter. A fine distinct halo occasionally is noted immediately about the ureterocele. In only 4 of 21 cases in which studies by excretory urography were made was the diagnosis of ureterocele established without the necessity of cystoscopy. In 1 other case the excretory urogram merely was suggestive of ureterocele.

Thompson and Greene state that if no symptoms of ureterocele are present and if the rest of the urinary tract shows no abnormality no immediate treatment is necessary; however, the patient should be informed of the presence of ureterocele in case symptoms develop in the future. In 9 of the 37 cases received no surgical or urologic measure was necessary. Cystoscopic dilation of the mouth of the ureterocele by means of ureteral bougies and catheters was employed in only 3 cases. Transurethral fulguration of the ureteral orifice or, better than that, ureteromeatotomy can be expected to yield the most satisfactory results. If the ureteral orifice cannot be located definitely, the most accessible point in the ureterocele may be selected for fulguration or incision. The incision should be large—equal to the diameter of the dilated ureter. Occasionally, the incision may need to be 2 or 3 cm. in length. Stones, if present, can be removed from the ureterocele at the time ureteromeatotomy is performed. In case serious renal damage has occurred, the performance of some surgical procedure on the kidney may be necessary. The authors say that the results of transurethral meatotomy have been satisfactory. In no case has it been necessary to perform nephrectomy at a later date, nor has it been necessary in any case to open the bladder suprapubically for additional treatment of the ureterocele. There was no death in the series of 37 cases.

(To Be Concluded)

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